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Forecast models for the main features of the pollen season and daily average counts for allergenic taxa in Central Albania

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FORECAST MODELS FOR THE MAIN FEATURES OF THE POLLEN SEASON AND DAILY AVERAGE COUNTS FOR ALLERGENIC TAXA IN CENTRAL ALBANIA

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ABSTRACT

The research for the thesis is related to the construction of long and short term pollen forecast models for Grass, Olea and Urticaceae in Albania which are the most allergenic taxa in this country.

Aerobiology, which is the study of organic particles (bacteria, fungal spores, pollen, small insects) passively transported by the air [Spieksma, 1991], has received very little attention in Albania. The research represents a major advance as it is the first work of this kind in this country.

The aims of the research were to investigate the features of the pollen seasons for the mentioned taxa as well as establishing relationships between these features and the main controlling weather variables. The achievement of these aims provided the basis for a further aim of the research which was to construct the long and short term forecasts for Grass, Olea and Urticaceae. Also the research investigated the possibility of constructing short term forecasts for the mentioned taxa on the non-rainy days.

The data used for the research were pollen data and meteorological data from Tirana city in the period 1995-2004. It was not possible to have data from the years 1997 and 1999, 2000, 2001 due to practical problems. The meteorological data for the research were obtained from the Meteorological Institute in Tirana.

In order to investigate the pollen season features, the pollen season for Grass and Urticaceae were divided into three periods, the pre peak, peak and post-peak since the behavior of the pollen seasonal variation curve differs according to the phases. The Olea pollen season is very short lasting for no more than 40 days so this was divided in two periods namely pre-peak and peak.

An important outcome of the research was also the production of a pollen calendar for the main allergenic taxa based on five years of data. The pollen calendar will be useful for allergists and the general public.

A lot of meteorological variables were used in the empirical analysis (correlation and regression analysis) in order to investigate which of the weather parameters give most explanation of the features of the pollen season. A number of variables were examined for possible inclusion in the linear regression analysis. The variables were selected after reviewing previous research on the effects of meteorological variables on the production of pollen from the three taxa.

Linear regression was used to construct the long term forecasts for Grass, Olea and Urticaceae while multiple regression analyses were used for the construction of the short term forecasts.

The forecasts obtained were able to forecast with an accuracy from 50-85% for Grass, Olea and Urticaceae. The models obtained for the non-rainy days were successful for Olea in the pre-peak period. No rainfall was recorded during the peak period. Also the Urticaceae models for the non rainy days were accurate only for the pre and peak period.

Neural networks were used as an alternative method to the regression analysis for Grass, Olea and Urticaceae and were very accurate. This method was able to forecast the daily variations of the mentioned taxa as a whole season as well as pre and post peak period. It also increased the accuracy to 96% to forecast the daily variations for the Olea in the pre-peak period and 82% in the post-peak period. The accuracy achieved for Urticaceae was 98% in the pre-peak period and 95% in the post-peak and whole pollen season respectively.

The skills gained and the forecast models that were constructed through this research will enable Aerobiology to be established in Albania as a scientific discipline. The work will allow the creation of a network pollen system similar to that in other European countries.

The results will be for use for the public, for doctors, pharmacists and related bodies.

The acquisition of more pollen data through the continuous monitoring sites in Albania will enable the constructed forecast models to be updated.

DECLARATION

I declare that this project is the result of my own work and all the written work and investigations are my own, except where stated and referenced otherwise. This thesis has not been accepted or submitted for any comparable award elsewhere.

I have given consent for my thesis, if accepted, to be available for photocopying and for inter-library loan, and for the title and summary to be made available to outside organisations.

Elona Gjebrea Hoxha

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CHAPTER ONE
INTRODUCTION

During the last few decades evidence indicates that there has been an increase in the prevalence of pollen allergy in most European countries [Spieksma *et al.*, 1989 a]. Pollen related allergy is a common disease resulting in symptoms of hay fever and asthma in about 10% of the population [D'Amato *et al.,* 1991 a] with notably higher prevalence rates in some countries, especially in young age groups. For example the ISAAC study showed that 35% of 13-14 years old in the UK have hayfever [Strachan, 1997] while a more recent study following the ISSAC methods showed increases to c. 38% in this age group. In Spain and Italy the comparable rates for 1991 are 9% and 16% respectively.

In some countries of Europe such as the U.K, Spain and Italy, pollen monitoring and forecasting is well developed. It has proved to be useful for many groups including allergy sufferers, medical professionals and pharmaceutical companies. In contrast many countries have very few pollen monitoring sites and no developed models for forecasting. This is the case in Albania situated in the eastern Mediterranean region with a population of 3.4 million inhabitants.

A survey was conducted by the European Community Respiratory Health Survey in Albania [Priftanji *et al.*., 1999] with subjects that were residents of Tirana aged 20-44 years. A total of 2653 subjects completed a screening questionnaire. A more detailed questionnaire was administered to a random sample of 564 respondents together with skin prick tests and serum IgE assays. The findings confirmed the hypothesis of a low prevalence of allergy in Albania. The results of skin tests have shown that the house dust mite was by far the most important allergen to which people were sensitized, followed by grass pollen. The results have shown that prevalence of specific serum IgE (501 specimens) to Parietaria was 7.6%, and to Olive was also 7.6%. Possible reasons for the low prevalence of allergy in Albania include the recent economic isolation of Albania, the infrequency of smoking by women, the lack of domestic pets and the high incidence of childhood infection and parasitic infestation. The prevalence of allergy and its potential determinants should be monitored in Albania as this country acquires the characteristics of other parts of Western Europe.

The most allergenic pollens in the Mediterranean countries are those belonging to Poaceae (Grass), Olea (Olive), Urticaceae (Nettle) [Frenguelli *et al.,* 1989; DAmato& Lobefalo., 1989].

Pollen from the grass family (Poaceae) is considered to be one of the most important aeroallergens in Europe. This is because of its ubiquitous nature and the allergenic capacity of pollen grains from its species. The grass family is highly adaptable and extremely large, consisting of about 620 genera and 10,000 species worldwide, with over 420 of these occurring in Europe [Emberlin, 1997; Galan *et al.*., 1989]. In Albania there are about 50 genera and 126 species widespread in all the regions of the country. Allergy provoked by the grass family has been described by numerous authors [Spieksma *et al.*, 1985; D'Amato and Spieksma, 1992; Newnham *et al.*, 1995].

The Olive tree is very common in Albania and is comprised of two species, Olea europaea L and Olea oleaster. The Olive tree, Olea europaea L. is one of the most characteristic features of Mediterranean flora. Olive pollen has been recognized as the most important allergenic pollen in the Mediterranean region [D'Amato & Lobefalo, 1989; Macchia *et al.*, 1991].

In Mediterranean climates, pollen from the Urticaceae family can be found in the atmosphere through out almost the entire year. The genus Parietaria belongs to the family of Urticaceae, together with the allergenically unimportant genus Urtica (nettle). Among the different species of this genus the most important are P.Officinalis and P.Judaica both present in the Albanian flora. Parietaria has been described as the one of most important allergenic plants in the Mediterranean areas by many authors [Bousquet *et al.*, 1986; D'Amato *et al.*, 1991 b, 1992].

Aerobiology, which is the study of organic particles (bacteria, fungal spores, pollen, small insects) passively transported by the air [Spieksma, 1991 b], has received very little attention in Albania. The current research represents a major advance as it is the first work of its kind in Albania.

The work described in this research is a programme for a PhD thesis.
The study is based on the pollen counts and the weather data from central Albania. The daily average pollen counts of airborne pollen have been monitored in Tirana since 1995 by the research student [Gjebrea *et al.,* 1998]. The study is original as it will build forecast models for the main features of the pollen season and daily average counts for main allergenic taxa in central Albania.

The monitoring and analysis of the pollen seasons will provide a new database for aerobiology. The forecast models will be useful for clinicians in planning treatment and for the public in planning their activities as well for the health care industry in providing better management of allergic diseases [Emberlin *et al.*, 1999].

1.1 Background of the research

Very little work has been done on aerobiology so far in Albania and information about the characteristics of pollen seasons is lacking. Without adequate knowledge it is not possible to produce pollen forecast models. A considerable amount of work has been carried out in similar Mediterranean climates such as in Italy and Spain and other climatic areas of Europe. This type of work has identified the main variables that influence pollen seasons. However the relative importance of factors and the details of their influence differs notably in different regions [Spieksma *et al.*, 1989 a].

The study is concentrated on the pollen from the Grass family, Olive and the Urticaceae family because of their importance from the allergological point of view mentioned in the introduction.

Pollen count is greatly influenced by the meteorological conditions before flowering occurs. The sunshine or temperature conditions also called primary factors, influence the growth and development of vegetal species, and so control the pollen production. At the time of blossoming, the secondary meteorological factors (sunshine, rainfall, relative humidity) condition the opening of anthers and so the release of pollen grains then tertiary factors (mostly wind) causes the grains to be scattered in the atmosphere [Laaidi K *et al.*, 1997].

Various methods have been developed for defining the variables, which influence the start of the pollen season and it has been found that normally this depends on the weather and especially temperature and rainfall in a certain period before the season [Frenguelli *et al.*, 1989, Spieksma *et al.*, 1989 b]. Emberlin *et al.* [1999] explained that the mean temperature and precipitation are the main controlling factors for the start of the grass pollen season.

Basically models in use for severity and length of pollen seasons also take into consideration weather variables like temperature and precipitation. Frequently there is a positive correlation between the start and severity of pollen seasons because both rely on common variables [Emberlin *et al.*, 1993 a].

Daily variation in pollen counts has also been found to relate mainly to temperature and humidity whereas other variables explained only two percent of the variation [Moseholm *et al.,* 1987]. Many studies from Mediterranean countries have identified the specific periods of the influence for the meteorological factors before the individual pollen season [Galan et al., 2001 b; Fornaciari *et al.*, 1998]. However, despite identifying the main relationships in these regions the models presented by them cannot be used effectively in other regions because of differences in topography, variation in local vegetation and climate.

Forecast models produced by aerobiologists have historically attempted to predict the following [Larsson, 1993]:

- Pollen concentrations for the next day or next few days (short- term forecasts)
- The principal characteristics of the main pollen season, such as the start date or severity (long-term forecasts).

In aerobiology, most studies related to forecasting models concentrated on the development of long-term models. The most representative works along these lines might include those of Davies & Smith, 1973; Bringfelt *et al.*, 1982; Arobba *et al.*, 1992; Galan *et al.*, 1995. The models themselves range from those based on correlations [Ljungkvist *et al.*, 1977; Makinen, 1977] to those involving nonlinear univariants [Antepara *et al.*, 1995; Norris-Hill, 1995] although most use linear and parametric statistics (usually stepwise multiple regression).

The current research involves the development and testing of short term forecast models for the mentioned taxa using statistical methods that include correlation, regression and neural networks. The accuracy of the forecast models was tested on the pollen data at Tirana during the 2003 and 2004 seasons.

The pollen seasons of 2005 and 2006 have also been monitored by the author but they are not included in the thesis. This is because it was necessary to spend the time analysis the data set to 2004. The inclusion of data from 2005 onwards was not practical due to the constraints of time.

1.2 Aims and objectives

The main aims of the research study are to:

1. Investigate the features (timing, severity, length of season, daily variation) of the pollen season for the main allergenic taxa in Albania.

2. Establish relationships between these features and the main controlling weather variables.

3. Build short-term daily forecast models for selected pollen types in Albania.

4. Build forecast models to predict the main features of the pollen seasons for selected pollen types in Albania.

The objectives of the study are to:

1. Provide useful information to assist in the diagnosis of allergic diseases and improvement of their management

2. Establish a database for pollen counts for use in agriculture and related disciplines.

3. Establish aerobiology as a scientific discipline in Albania.

CHAPTER TWO
LITERATURE REVIEW

The review considers publications in the areas relevant to the main themes of the research project. It pays particular attention to the topic of forecasting and the associated methodology required for defining pollen seasons.

2.1 Forecasting the start of the pollen season

Aeropalynology is a useful tool to predict the beginning of the pollen season of plants producing allergenic pollen and of those with agricultural importance [Spieksma & Nikkels, 1998: Frenguelli *et al.*, 1992]. One of the most important of aspects of aerobiological studies is to find prediction models helping us to establish the onset of a pollen season. The forecast of the pollen season's start has a particular importance because this information is very useful for accurate use of medicine for allergies and for planning of the patient's activities.
Several studies have been published based on different methods for forecasting the start of the pollen seasons.

2.1.1 Defining the start of the pollen season

There is no general agreement about threshold levels of pollen necessary to cause symptoms of pollinosis season, and subsequently definitions of the various pollen seasons differ a lot. Partly as a result of this, analogous groups of patients show considerable diversity in the start and the duration of seasonal medication [Driessen *et al.*1985, 1987].

According to Frankland and Davies [Davies and Smith, 1973], a pollen count of 50 grains/m3 of grass of air in central London, UK, is enough to cause symptoms in 100% of sensitive patients. This can be expected to be a threshold value for similar urban areas However, no research work has taken place into the pollen threshold required to give symptoms in 100% of sufferers within a rural population who are not exposed to high air pollution levels.

Mullenders *et al.* [1974] stated that "the principal period begins the day when the 5-days running mean concentration reached at least 1% of the total annual sum on three consecutive days, and ended when the concentration was less than 0.9% of the total annual sum for more than 10 days. They used the concept of the initial, the optimal and the terminal phase in pollen calendars for a given season. This method was used by Spieksma *et al.* [1989 b] for their study of Alnus, Poaceae, and Artemisia between Central Italy and Netherlands. The same method was used by Frenguelli *et al.* [1991] for starting dates of the pollination period of Alnus and Populus between Central Italy and the Netherlands.

In 1981, Nilsson and Persson defined the main pollen season as the period between the day when the cumulated daily means reach 5% of the total annual sum, until the day when it reaches 95%. This work has been adopted by Larsson [1993] who studied the incidence of Betula, Pinus, Poaceae and Juniperus pollen in Sweden.

Galan *et al.* [2001 b] used in their study the "Method 1" for Olea where the start of Olea pollen season was defined as the date on which 1 pollen grain/m^3 daily average was recorded on 5 consecutive days. The same method was used for defining the start of Oak pollen season by Garcia-Mozo *et al*. [2002].

In her study Levetin, [1998] used as the beginning of the main pollen season for Ulmus, Betula, Quercus, Cupressaceae, the date when the cumulative total pollen reached 5% of the season total.

Also Lejoly- Gabriel, [1978] defined the start of the pollen season as the day when the sum of daily pollen concentrations reaches 5% of the annual total, provided that this particular day contributes at least 1% itself. The season ends on the last day when the daily percentage is greater than or equal to 1%, and the sum of the pollen percentage for this day and the preceding days is greater than or equal to 3%.

Diaz de la Guardia *et al.,* 1999, used as main pollen season the 95% of the annual sum, using cumulative values as Pathirane, 1975. The beginning of the season was the first day of a period of five consecutive days on which pollen grains were recorded. The initial and final 2.5% of the annual variation curve were eliminated to avoid lengthy tail-offs.
All these methods mentioned are not useful for predicting the start of the grass pollen season for hayfever patients, because all them can be used only in retrospect after the end of the pollen season.

The pollinosis season starts when the air contains a sufficient amount of allergenic pollen to cause symptoms of pollinosis [Driessen *et al.*, 1989]. Although the relationship between the pollinosis season and the grass pollen season is not known exactly [Spieksma *et al*., 1980; Spieksma *et al.*, 1985] it may be considered that a prediction of the start of the grass pollen season can be used to forecast the start of the period of potential pollinosis symptoms.
The criterion for the starting date of hay fever symptom has been formed from the data of the daily hay fever warning system which is based on the relationship between the flowering development of the wild grasses (phenology), the actual weather situation and on pollinosis symptoms based by a report of a group of patients. [Spieksma and Nikkels, 1998].
Different methods have been developed, especially for the definition of the start of the season [Larsson and Nilsson, 1991]. These methods include the sum 100 and the sum 75 methods which is when the cumulated sum for the daily average concentrations reaches 100 and 75 correspondingly.
Driessen & Spieksma., 1990 were interested only in the start of the grass pollen season and not the duration and therefore they defined the start of the season as the day when the cumulative total pollen catch reached 50, 75,100 and 125 grains m^3. These four values were designated the □50, □75, □100 and □125 methods respectively.
The start of the flowering of grasses, however, depends only on the weather conditions preceding their flowering. There are many difficulties relating to the definitions of the start dates. For instance, the validity of using the sum 75 rather than the sum 50 or the sum 100 is still not defined precisely by many researchers in the field of aerobiology.

There have been many alternative attempts towards the statistical definition of the start of the grass pollen season and another attempt is the 98% method using a statistical definition based on the total catch for the season. Pollen seasons were defined [Emberlin, 1993, a] as the period in which the 98% of the total catch occurred. The season was defined to have started after the 1% level was reached and similarly ended at the 99% level. The technique of defining the season avoids distortion that could occur incidentally through localised flowering at the start of the season and resuspension at the end [Emberlin *et al.*, 1993, b]. The 98% method has the disadvantage that is relative to the total pollen catch so it may bear little relationship to concurrent weather conditions, but it helps to facilitate comparison between sites [Emberlin *et al.*, 1994]. However this method can only be applied retrospectively and is not a useful measure in terms of forecasting the pollen season.

The sum 75 method appears to be a better definition than the 98% method for hay fever and asthma sufferers because it is an absolute value but it is clearly influenced by the abundance of local grasses [Emberlin *et al,* 1994; Jones, 1995]

Pollen data can be used as a phenological indicator of flowering, and many phenological studies using pollen data have been conducted in order to determine the chilling and heat requirements for flowering in various species and geographical areas [Garcia-Mozo et *al.,* 2002; Jato *et al.,* 2000; Fornaciari *et al.,* 2000; Galan *et al.,* 2001, a].

For future work, a different attempt needed, maybe using curves for cumulative counts where the start of the season is defined when the gradient of the curve reaches a certain relationship. This would enable the production of absolute values but also it will help to make comparisons between sites [Emberlin *et al.*, 1994]. Also it should be noted that different definitions of the start dates might be appropriate for different taxa.

2.2 Timing

Weather conditions directly influence pollen counts by influencing pollen production, the time of the start of flowering, the abundance of vegetation and by controlling the amount of pollen daily into the air.

It generally accepted that the timing of seasons can vary to a great extent from year to year, depending mainly on cumulated temperatures over 5.5°C [Spieksma *et al.* 1989, a] and precipitation in the months proceeding the flowering period [Emberlin *et al.*1990]. The relative importance of these factors varies in different climates with the temperature as the most important at higher latitudes. Pollen "hot and low spots" occurr in relation to local weather, topography and vegetation.

In order to forecast the start dates, duration and severity of the grass pollen seasons in London, Emberlin *et al.* [1993, b] used multiple regressions to analyse meteorological and pollen data for a period of 20 years [1971-1990]. The annual start dates, length of season and severity were observed in relation to the main meteorological variables of cumulated temperatures above 5.5°C and precipitations measured at one site within London and two sites in the surrounding rural areas. Land use changes also were considered. Grass pollen seasons have a tendency to start later over the two decades considered despite an increase in flowering grasses related with the set aside policy and uncut verges. They found that the date of the start of the grass pollen season in London differed by 28 days for the period of 20 years, with early start dates positively correlated with monthly-cumulated temperatures above 5.5°C, considered from 1st January. Using multiple regression analysis predictions of the main characteristics of the pollen seasons could be made relatively early in the year through the use of these models by using the monthly weather forecasts related with long term average weather profiles.

Also Emberlin *et al.* [1994] studied the start of the grass pollen season over many areas of the U.K, for a six-year period. Differences in the start dates were observed in relation to cumulative temperatures above 5.5ºC and monthly total rainfall from February to the end of June. It was seen that seasons often start simultaneously in the south and west part of the UK. The variation in start dates showed a relationship with cumulative temperatures and rainfall in May and June but the patterns were not easy to clearly explain. Perhaps future work should analyse the data from the full geographical range of the network of aerobiological stations.

Spieksma *et al.* [1995] studied the birch pollen measured at five sites in Europe for a period of 18-30 years. This has been studied with particular consideration for three aspects: trends and fluctuations of annual sums of daily concentrations and starting dates of airborne presence. The quantities were connected probably due to synchronous aberrant years and phase shift. The air temperature during the preceding 4 decades of days was important for the starting dates of the birch pollen season.

The relationship between the timing of olive pollen release and some parameters, which can influence the timing of Olive was observed by Formaciari *et al.* [1998]. A model offered by the authors shows a clear relationship between the timing of pollen release, precipitation, temperature and annual pollen quantity. The most important correlations were achieved when the mean temperature in February and precipitation in May were used. The positive correlation with annual pollen quantity strengthens the relationship of this variable to the time of pollen release.

Earlier international studies that have compared amounts of airborne pollen between two very different climates have revealed big differences in the characteristics of the pollen seasons [Lejoly-Gabriel & Leuschner 1983; Spieksma *et al.*, 1989 a, b]. From the results of the analyses the major opinion suggests that temperature is the factor that exerts most control over the start of the season and the peaks.

Spieksma *et al.* [1989, a], in a comparative study of airborne pollen concentrations in Central Italy and the Netherlands compared the airborne pollen concentrations of three taxa Alnus, Poaceae and Artemisia typical for the three seasons of the flowering period in two different and separated types of climate in Europe.

The start and the main period in early spring of the season of Alnus pollen were correlated in both regions with the air temperature in the preceding months. Poaceae pollen, presenting 10-20% of the total annual pollen concentrations in both regions, has its start and main season in late spring, about one month earlier in Central Italy than in the Netherlands, strongly correlated with the air temperatures in April and May .The main period and the start in late summer of the season of Artemisia pollen, with low concentrations in both regions, was about 10 days earlier in the Netherlands. This seems to be in the inverse way correlated with the air temperature in June and July, suggesting a postponing influence on pollen release of higher temperatures, possibly by invigorating vegetative growth during the warm summer period.

The difference in the peak concentrations of three selected taxa was observed in the two regions and the differences that does occur result mainly from the climatic differences between Central Italy and the Netherlands.

A study conducted by Spieksma *et al.* [1989, b] was based on airborne grass- pollen concentrations in six cities (Copenhagen, Cardiff, Leiden, Brussels, Naples, Munchen) during five years 1982-1986.

Airborne pollen concentrations not only differ from place to place, and from year to year in a quantitative way, but also with respect to their seasonal courses. For example there is a general trend of a later grass-pollen season in the northwestern part of Europe than in the Mediterranean region as has also been reported before by authors as Bagni *et al.*, 1976 and Spieksma *et al.*, 1989, a]. The meteorological factors play a decisive role in the starting dates of the pollen season. Also local factors, such as the existence or not of nearby parks or gardens, prevailing wind directions combined with the orientation towards large source areas, might be a big influence.

Koivikko *et al.* [1986] conducted a study in order to forecast the pollen seasons of Alnus, Betula, Poaceae and Artemisia, the most allergenic plants in Finland. With the exception of Betula pollen, the allergenic pollens in Finland occur in lower concentrations than in central Europe. There were large annual variations in the start of pollen seasons and the quantities of pollen. The variations in the start of the Betula and Poaceae pollen seasons seemed likely to depend on the mean temperature in April.

Emberlin *et al.* [1997] conducted an investigation for an apparent trend towards earlier birch pollen seasons in the U.K, in order to determine if the earlier start dates were a biotic response to changes in weather conditions due to climatic change. Pollen counts and meteorological data from three sites, Cardiff, Derby and London were used to carry out correlation analysis. Spearman's rank correlations between five years running means of monthly cumulated temperatures and start dates of the birch pollen seasons showed significant relationships at three observed sites, representing the occurrence of a biotic response in the timing of the birch pollen season. This study is related to the work of Jones [1995] who identified significant relationship between the start dates of the birch pollen season and monthly temperatures for late winter and early spring both as average and cumulated values for all three sites.

Frenguelli *et al.* [1991] conducted a study on the changes of airborne pollen presence in the atmosphere of Perugia (Central Italy) for a period of 20 years. The changes from year to year in the date of first flowering of many taxa could be an easy indicator of the changes in air temperatures recorded in these last decades probably due to global warming. In the study area, annual mean temperatures were increasing on average by 0.7ºC. Linear regression of the time series used in this study showed that there has been a statistically significant linear trend, particularly in the spring period, towards earlier pollen release.

2.3 Severity of the pollen season

In 1973, Davies and Smith were among the first people to forecast grass pollen concentrations in Britain. Following on from their previous regional comparative work [Davies *et al.*, 1963; Davies, 1969], they attempted to forecast the start and severity of the grass pollen season. This work was among the first work to consider the controls on grass growth and flowering, and it was concluded that the severity could also be predicted on the basis of cumulative pollen counts during the season. It was also pointed out that temperature in April and May is the decisive factor leading to growth to the pollen potential for these seasons.

Some authors argued that meteorological conditions could influence the pollen season timing as well as its quantitative importance. For example, Andersen, [1980] working in Denmark, studied the influence of climate on the pollen season, but he was mainly concerned with its influence on severity, particularly in the cases of Birch, Alder, Oak, Beech, Grasses and Nettle. He concluded that Birch and Alder behaved in the same way as they both tended to flower in abundance biennially and he showed that the flowering intensity of birch and alder in Denmark depends on the precipitation of April of the previous year, while the flowering intensity of Oak and Beech would depend on the average temperature of the previous year. It was concluded that the length and severity of the pollen seasons are related more to pollen productivity in the particular years [Davies & Smith, 1973].

A regression analysis between pollen quantities, average humidity of November and December and average soil temperature at fifty centimetres for the same months was established by Lejoly-Gabriel [1978].

Laaidi [2001] showed in his study that pollen quantities depend not only on meteorological conditions before pollen release, but also maybe on those prevailing during pollen release (pollen wash-out by rainfall, stopping of pollen grains release in the occurrence of frost etc).
Larsson [1993] in Stockholm made an effort to predict the start, peak and the end of the pollen season with the cumulated activity method using a development of the temperature sum method. The aim of the study was to calculate activity which corresponded to the efficiency of processes in the plant that are relevant for the development and shedding of the pollen grains. The activity formula was calculated using daily mean temperatures and eight pollen types were used to test the model. It was found that this method was appropriate for those trees that do not flower early in the spring such as Betula, Ulmus and Pinus but was not so appropriate for Corylus, Poaceae and Artemisia.

To forecast start dates, duration and severity of the grass pollen season in London Emberlin *et al*. [1993, a] developed some statistical models based on multiple regressions, using meteorological and pollen data for a period of 20-years. The regression model used could predict the severity of the grass season at the end of May or when the sum 75 figure had been reached by using the monthly forecasts of temperature and precipitation in June. It was found that predictions could be made at the end of April when the temperature and precipitation variables were replaced with long-term weather forecasts for May. The duration of the grass pollen season showed a positive correlation with severity, since both depend on common variables. It was possible to predict the duration of the grass pollen season to within five days of the actual date when the data were tested on two years (1991, 1992).

Also Emberlin *et al.* [1993, b] investigated the start and duration of the Betula pollen season as well the annual patterns in pollen abundance in London. By means of multiple regressions they were able to predict 80% of the start dates in a period of 7 days. The variables incorporated in the analysis were mean temperature in December and January, accumulated daily March temperatures and mean temperature and precipitation in February. When all significant variables of temperature and precipitation were incorporated into multiple regression models an explanation of 30.8% was achieved to predict the duration of the Betula pollen season and 41.5% explanation when the severity of the season was predicted.

Dahl and Strandhede [1996] developed a model for predicting the severity of the birch pollen season. They stated that the temperature sum and the total amount of pollen collected during the period of catkin commencement (May 1^{st} to July 20^{th}) could be used to forecast the severity of the following years pollen season by using regression analysis

Empirical statistical models were developed by Emberlin *et al.* [1999] in order to predict the severity of the grass pollen season in the U.K. The grass pollen seasons were analysed for three different sites to provide regional insight to the regards of changing incidence of hay fever. Analysis of grass pollen seasons in three defined sites showed that the cumulative count 75 threshold could be used as an indicator of the time when the main grass pollen season started. The maximum explanation in forecast models was obtained when ten-day aggregates of cumulative daily temperatures above 5.5°C and precipitation were used. The models showed that importance of the variables that influence the total catch in the three studied sites. In all three sites better predictions could be made in those years when the weather pattern is near the mean condition. It was suggested that the high percentage explanation derived from the fact that weather at the time of flowering of individual grass species is not important as for the start dates. In this study the models could serve as a useful basis for forecasting severity at a relatively early stage in the year.

A statistical regression analysis was used by Jones in 1995, to predict the start and severity of grass and birch pollen seasons at a network of sites in the UK. The results of this study showed that similar factors influence in the start date and severity of the grass pollen season (temperature at the end of winter time and the beginning of spring time, and temperature and rainfall during spring time). Three statistical models were developed, enabling the prediction of the grass pollen season within four days of the actual start dates with a accuracy of 100%, 77%, and 61% at London, Cardiff and Derby respectively. It was shown from this study that the statistical models used to predict the total seasonal catch reached higher explanation than the start of the season models probably as the variations in flowering times between grass species is not as important as it is when predicting severity.

Galan *et al.* [1995] through a comparative analysis of daily variations in the Grass pollen counts at Cordoba, Spain and London, U.K studied the characteristics of five grass pollen seasons from two areas with different climate. Also the relative importance of the variables controlling daily variations was considered. It was found from this work that the length of the seasons differs significantly between the two locations and from year to year.

Hallsdottir, [1999] have analysed the birch pollen abundance in Reykjavik, Iceland for a ten year period. A three-year cycle was observed for the annual birch pollen sum which could give explanations in forecasting the severity of the next birch pollen seasons. The annual birch pollen sum was regressed taking into consideration six climatic variables. Only one of which was found to be statistically significant. The number of days with temperature above 7.5°C in the year of inflorescence initiation showed a significant correlation with the annual birch pollen sum of the following year. The accumulated thermal sum on May 15 was shown to have the best predictive value, estimating it to within one week with regards to the starting date of the birch pollen season The mean duration of the birch pollen season in southwest Iceland is 17 days, with a start of pollen season in May 29 and the end of the pollen season in June 14.

Marked decreases have taken place in the severity of grass pollen seasons in London, particularly between the 1960s and the early 1970s but also over the period to 1995 [Emberlin *et al.*, 1993, b]. The decrease in the annual totals of grass pollen counts in London seems to be connected with the land-use changes. Changes in grassland utilisation with the respect to pollen production and hayfever in the U.K, was discussed by Hopkins and Davies [1994].Among the common species of U.K grasses, Dactylis glomerata produces the large quantities of pollen, more then twice that produced by Lolium spp with Phleum spp intermediate. It was suggested by the authors that changes in grassland utilisation have led to a progressive decline in pollen production during 30-40 years, from a peak in the earlier part of the century. Recently agricultural management with botanically diverse swards and late (post anthesis) mowing for hay, has been replaced by more intensive management with more reliance on Lolium perenne and early mowing for silage. The role of Dactylis glomerata and Phleum pratense has declined. A decrease in the pollen catch during June helps to give a better understanding of the hypothesis that these changes have affected the quantities of pollen released. According to authors of this study, the incidence of hay fever showed geographical variation with climate, topography and vegetation type.

2.4 Daily forecast models

Daily variations in pollen count have been found to relate mainly to temperature, precipitation, humidity and wind. This has been reported by many authors [Spieksma, 1980; Moseholm *et al.*, 1987; Goldberg *et al.*, 1988; Sanchez Mesa *et al.*, 2003; Emberlin *et al.*, 1994]. However relationships found in one area cannot always be applied to a different area with the only justification that meteorological parameters are inter-correlated and are dependent on a particular site [Moseholm *et al.*, 1987]. The relative importance of these factors is different in different regions. In order to build more precise daily forecast models it is important to understand and investigate the relationship between dependent and independent variables in a particular study area.

Bringfelt, [1980] used correlation and regression analysis on pollen counts in Stockholm, Sweden. Bringfelt *et al.* [1982] developed this work with predictive models for the Betula and Poaceae pollen season by means of multiple regression analysis.

Also Spieksma, [1980] developed a model to make a daily hayfever forecast for the Netherlands based on a regression analysis similar to that of Bringfelt, by the use of fewer meterorological variables. Spieksma *et al.* [1985] based on 5 years observations, found a rise in temperature in the last week of May or the first week in June in the pattern of the start of the season in the Netherlands, and although a long term prediction for the start of the season is difficult to realise, a short –term forecast based on weather, pollen concentrations and patients complaints records achieved an accuracy of over 80%.

Galan *et al.,* 2000*,* studied the meteorological factors that influence the daily Urticaceae pollen counts in southwest Spain. The highest correlation between pollen concentration and meteorological parameters was obtained during the non-rainy seasons. Temperature was found to be the most important meteorological parameter influencing pollen counts in spring. Temperature is the main reason for the increase of the pollen concentration in the atmosphere. In autumn, humidity was another parameter influencing pollen counts. Rain did not appear to be significant.

The data of pollen concentrations and meteorological data from five years (1987-1991) in North London were used by Norris-Hill, [1995] to develop models to predict daily Poaceae pollen counts. This study was original in attempting to forecast daily pollen concentrations based upon an estimate of the potential severity of the season instead of using a retrospective record of pollen abundance as other authors have showed. These models were developed using different techniques including the use of third –order polynomial curve to forecast potential pollen concentration and the use of accumulated meteorological variables. Then they were tested for accuracy in 1991. When the weather variables like accumulated average temperature, daily rainfall, relative humidity and maximum temperature were incorporated into the model, the accuracy was 71% for the

1991 season. It should be noted that these models are designed specifically for their easy way of use in practice and their reliance on meteorological variables that may be forecast in advance as the author suggests in her study.

Galan *et al.* [1995] produced a comparative analysis of daily variations in grass pollen counts in Spain (Cordoba) and the U.K (London).The grass pollen data in two sites were analysed in regards to the meteorological factors. Using the regression analysis it was shown that for London, maximum and average temperatures were the most important factors influencing daily variation for grass. For Cordoba this relationship is true only for the part of the season from the start until the peak count. After this period the relationship between meteorological variables was negative. Also the study showed that the hours of sunshine and humidity had an importance. Using regression analysis it was shown that the increase of humidity has a negative effect on pollen release which it was more marked in Cordoba. The results from the study emphasised the need for more work on individual analysis in different climates as well as using the applications of different statistical methods.

Relationships between daily grass pollen concentrations and weather conditions such as temperature, humidity, precipitation and wind have been reported by many researchers including Spieksma, [1980]; Moseholm *et al.* [1987]; Goldberg *et al.* [1988]; Agashe & Alfadi, [1989] but most studies have been of single regions or under similar types of climate.

A study was conducted from Fornaciari *et al.* [1992] in order to forecast daily variations of Urticaceae pollen counts in the atmosphere of East Perugia, Italy. The meteorological parameters such as temperature, relative humidity, rain and wind speed were included in this study. It was shown how the pollen concentration is affected by all climatic parameters during dry days only. An uncharacteristic pattern was observed during rainy days and the best correlation was with meteoclimatic parameters during non-rainy days. The interpretation of the influence of rainfall was very difficult due to its peculiar features in summer.

Trigo *et al.* [1996] conducted a study to investigate a connection between the meteorological parameters and annual, daily and diurnal variations of Urticaceae airborne pollen in Malaga, Spain for a period of three years. They analysed in their study three meteorological factors, maximum air temperature, sunshine hours and relative humidity. It was shown that the best correlation was with sunshine and maximum temperature. The correlation analysis showed negative coefficient values for relative humidity and this negative correlation was perhaps linked with the fact in the study area relative humidity was very high. Also negative correlations were observed with rainfall.

Galan *et al.* [2000] developed a daily forecast model for Urticaceae (Nettle) for Spain. Statistical analysis was undertaken to identify the influence of meteorological factors on the daily Urticaceae pollen counts for the period 1996-1997. Among the meteorological factors studied were the mean, maximum, and minimum temperature, daylight hours, humidity, the mean temperature of the previous day as well as the sum of the mean temperature of the 2 previous days.

It was shown that temperature gave the best correlation with pollen counts in spring and temperature and humidity gave the best correlation in autumn. The effect of humidity on the pollen counts was negative when it resulted from heavy rainfall and positive when it resulted from light rain distributed over many days. Rain, however, did not give significant results with statistical analysis perhaps linked with the fact of the opposing effects of rain intensity on pollen counts: decreased pollen concentrations were recorded on days with heavy rainfalls and increased concentrations were recorded on days with light rainfall. It was suggested that the pollen concentration of the previous day is an important variable in predicting the Urticaceae pollen concentration when rainfall is not very high. Anyway, this was a preliminary study based on data of 2 years; the results achieved are only a rough indication of which variables are useful to predict Urticaceae pollen counts. In future additional data collection is required to set up the efficacy of this model and to allow precise conclusions to be drawn.

Simple and multiple linear regressions were used from Recio *et al.* [1997] to forecast daily airborne olive pollen during the pre- peak period in Malaga, Western Mediterranean area. It should be noted that very few studies present predictive models even though Olive pollen is one of the most common aeroallergens in the Mediterranean area

According to the authors the pre-peak period was defined as the period running from the beginning of the main pollen season until the day when the maximum counts were recorded. Given that the pre and post-peak behaviour was seen to differ, the whole pollen release period was not considered. The study took into consideration only two meteorological parameters, accumulated temperature and rainfall from the time of manifestation of flowers buds. It was shown by means of statistical analysis that the daily variations in airborne olive pollen during the pre-peak period depend more on accumulated temperatures from the chilling requirement for flowers buds initiation, than on accumulated rainfall. The model was based on 4 years data and it was achieved an accuracy of 50%. In the case of a meteorologically uncharacteristic year, the same regression equation can be applied, although the degree of expectedness will be to some extent lower.

2.5 Neural networks models

In recent years, neural network use has spread to practically all sciences, particularly in pattern classification and non-linear models of prediction. A neural network consists of a mathematical model that performs a computational imitation of the behaviour of neurones in the human brain by replicating on a small-scale the brain's patterns, in order to form results from the events perceived. It is about being able to analyse and reproduce the learning mechanisms and recognition of events possessed by the more highly evolved animal species. The performance of neural network models can be attributed to their structural and functional characteristic, such as the nonlinear model capability and the universal function of the approximation [Arca *et al.,* 2004]. Those characteristics suggest that the use of neural network models as a tool to forecast pollen concentration and to support preventive allergic therapy as other statistical models, neural network models require local calibration to produce reliable results [Arca *et al.,* 2004].

Sanchez-Mesa *et al.* [2002] used the neural network approach to construct models for forecasting the daily grass pollen concentrations in the southern part of the Iberian Peninsula. Linear regression models and co-evolutive neural network models were used for this study. The set of data includes a series of 20 years, from 1982-2001. It was observed that cumulative variables and pollen values from previous years are the most important factors in the models. The work indicated that in general neural network equations produce better results than linear regression equations.

A neural network model for grass pollen forecasting was presented by Ranzi *et al.* [2003] in Emilia-Romagna (Italy). The performance of this empirical model was satisfactory, in particular regarding the prediction of the starting date of the pollen season. The study has shown that the relationship between pollen concentrations and meteorological situations are independent from site. It was suggested by the authors that such models understand the differences in area through phenological and meteorological information. The neural network model showed its intrinsic robustness in forecasting unknown years. The differences between areas could be interpreted by the model by means of changes in weight matrix and in meteorological thresholds values.

Arca *et al.,* 2004, used a neural network to short-term forecast of airborne pollen data for Graminaeae for 1-7 days ahead. Artificial neural networks were realised using a three-layer feed- forward topology and the backpropagantion learning optimization algorithm. The processing elements (PEs) of each layer were fully connected to the PEs of the next layer. The technique of a one-lag was used which allow only past values of input variables to used for performing forecast for Graminaeae. The metereological variables used were air temperature, wind speed, rain intensity. The inclusion of the air relative humidity variable to the data set did not improve the accuracy of the model. It was found that correlation coefficient between observed and predicted daily grass pollen counts was from 0.81-0.99** for one to seven days ahead.

These few attempts at using neural networks for pollen forecasting indicate that there is a potential for developing accurate models in this way but more needs to be done in this theme. In particular the approach needs to explore the use of additional variables and needs to be applied to a range of taxa. The methodology of the neural network could also be developed and enhanced by investigating the most appropriate design and complexity of the two models.

CHAPTER THREE
LOCATION AND GEOGRAPHICAL BACKGROUND

3.1 General Introduction

The Republic of Albania is a southeaster European country. It is located in the West of the Balkan Peninsula between the geographical co-ordinates 39°16' latitude and 49°39' longitude (Fig. 1). Albania is one the smallest countries in Europe, it is 335 km from north to south and 150 km from east to west. To the north, northwest and northeast it borders Yugoslavia. The former Yugoslav Republic of Macedonia is to the east and Greece is to the east and southeast. The Adriatic Sea lies to the west and the Ionian Sea to the southwest. The two seas are joined by the Strait of Otranto, a narrow body of water between Albania and Italy. The Greek island of Corfu lies 5 km off the coast of Albania at its southernmost point.

More than three-quarters of the country is mountainous. In the northern part of the country are the Albanian Alps, with many peaks higher then 2000 metres. Along the coast is a lowland area. About the 40% of the land is forested, mostly with oak, pine and beech [Minxhozi, 1970].

In the western part of the country lie the western Lowlands, with a mainly plain relief and rich vegetation of this type. Along the whole coastline, in the lowland area from Shkodra to Vlora, there are numerous beaches with a Mediterranean climate.

The Western Lowland area has a lot of surface water. It is permeated by numerous rivers and spotted by lakes of tectonic and karst origin. In the northern part of the lowland area, there is the Shkodra lake. The Shiroka beach stretches along its shores. Along the Adriatic coastline, the Western Lowland areas form numerous bays with clear water and fine sand, which are very suitable sites for coastal tourism. The central Mountain Region lies in the Eastern and South- Eastern part of the territory. It is characterized by a rich Mediterranean and continental vegetation. The highest peak of the country (Mount Korab 2751m) is in this region. The Southern Mountain Region consists of mountain ranges, slopes, and separated mountains. The coastal area of this region has been named the Albanian Riviera. The Northern Mountain Region has mainly an Alpine relief characterized by a cold climate, alpine karst hydrograph and with partially endemic but rich vegetation.

3.2 Climate characteristics of Albania

The climate in Albania is typical Mediterranean. It is characterized by mild winters with abundant rainfall and hot dry summers.

The atmospheric conditions that influence Albania's climate are mostly depressions coming from the North Atlantic and being developed in the Mediterranean Sea (particularly those in Genoa Bay).

The frequency of cyclones and anticyclones has a specific annual structure. Cyclonic weather has a high frequency during winter months, giving clouds and heavy rains. Anticyclonic weather is more frequent during the summer. For that reason, during the summer high pressure predominates with clear sky with occasional clouds and the rainfall. In many years there are 2-3 summer months without rain. Temperature levels are high, particularly inland where temperatures are higher due to a weaker cooling effect of the sea. In the other parts, differences in landscapes and topography produce changes in local climate.

The geographic position of Albania results in a Mediterranean climate in the western lowland coastal area and continental climate in the remaining areas with a high number of climatic regions for so small an area.

According to the Hydro-Meteorological Institute (1988), there are four climatic subdivisions within the country: The Mediterranean flat zone, the Mediterranean hilly zone, the Mediterranean sub-mountainous zone and the Mediterranean mountainous zone.

1. The flat zone, which is mostly the coastal area, has relatively dry and hot summers with mean temperature of 26°C and mean humidity of 60% in July and August. Winters are cool and wet with mean temperatures in December and January of 11.8 °C and 9.8°C.

2. The hilly area stretching from north to south and located on the eastern side of the coastal zone is divided into three parts: northern, central and southern sub-zones.
Hills reach an altitude of 300 to 500m and have similar climate characteristics of the flat zone.

3. The sub-mountainous zone is comprised of highland plains in the south (plain of Korca) and river wallets in Peshkopi, Kukes, Tropoje, Puke. The altitude is about 800m and the mean temperatures are 3-4°C lower than the coastal plain and have frequent frost. The plain of Korca is an important agricultural area.

4. The mountainous zone that covers all lands above 800m has a continental climate. Annual precipitation is 1000-1800 mm, and in the Northern Albanian Alps it exceeds 2000 mm. Maximum summer temperatures are always below 25°C, while minimum temperatures can be as low as – 25°C. This is an area covered mostly by forests and natural pastures.

3.2.1 Temperature

Fig.2 shows annual average temperature distribution, minimum mean temperature and maximum mean temperature for three different stations situated in different climatic areas of the country. It's obvious that the annual pattern of changes for all the indices is similar. Maximal values happen during summer time (July – August) and minimal temperatures are in winter (January). Annual maximum temperature mean varies from 11.3°C in highlands up to 21.8°C in seaside and low zones. Minimum annual temperature mean varies from – 0.1 up to 14.6°C respectively.

This figure, showing a map of Albania, has been removed due to 3rd party copyright. The full unedited version of the thesis may be consulted at the Lanchester library, Coventry University.

Fig.1 Map of Albania

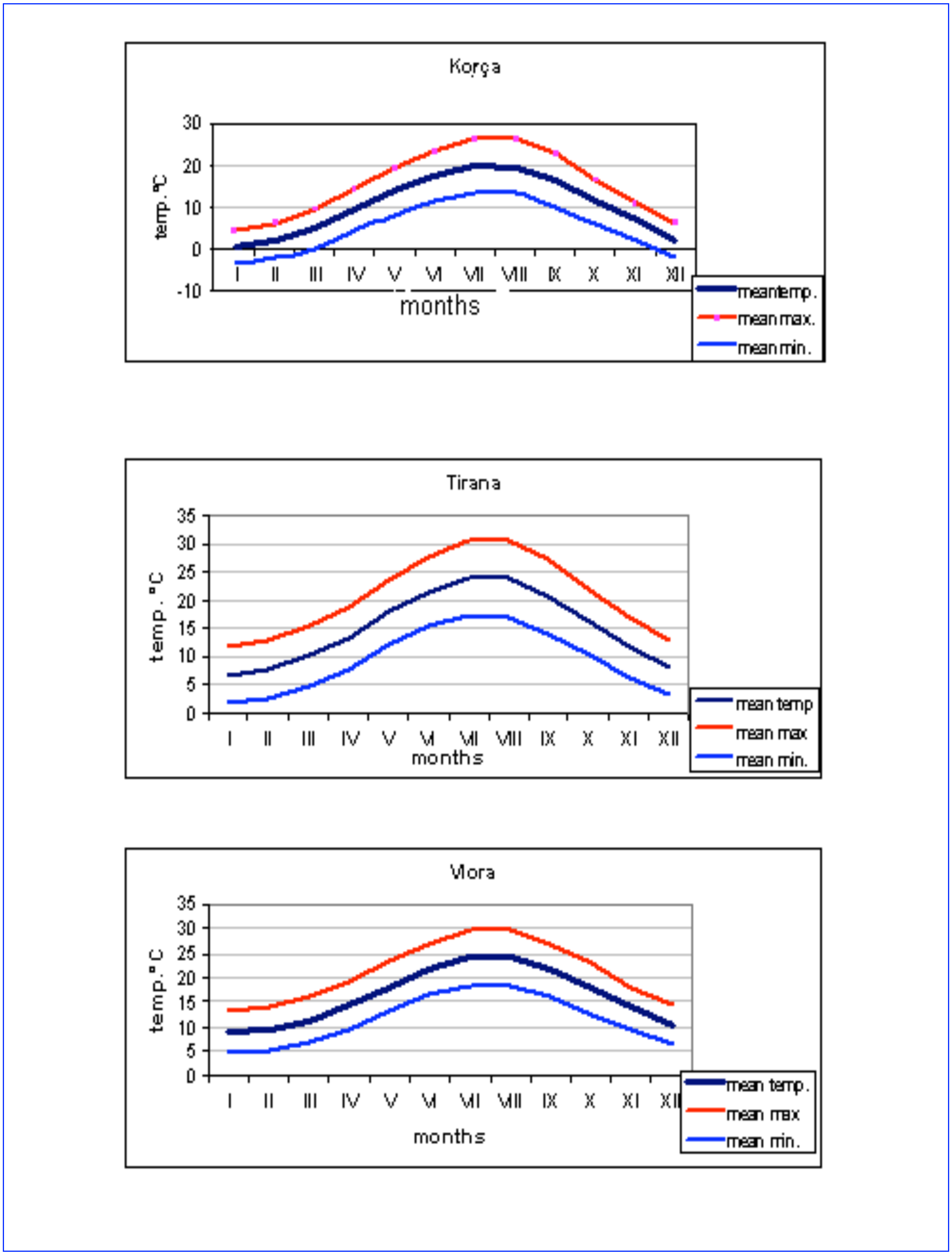


Fig.2 Annual average temperature distribution, mean temperature mean, maximum temperature mean for three different stations in Albania for 1961-1990

To study temperature variation for the period 1961-1990 the trends and the skim average of 22 stations in Albania's territory have been analysed. Fig.3 represents seasonal and annual anomalies only for Tirana. Generally results that the annual temperature mean shows a negative tendency of 0.6°C for Vlora station (southwest), 0.4°C for Shkodra station (northwest) and 0.3°C for Korça (southeast) during 30 years. Within this general tendency there are a few sub-periods with different tendencies, but during the last 15 years positive values are noticed almost in all three stations.

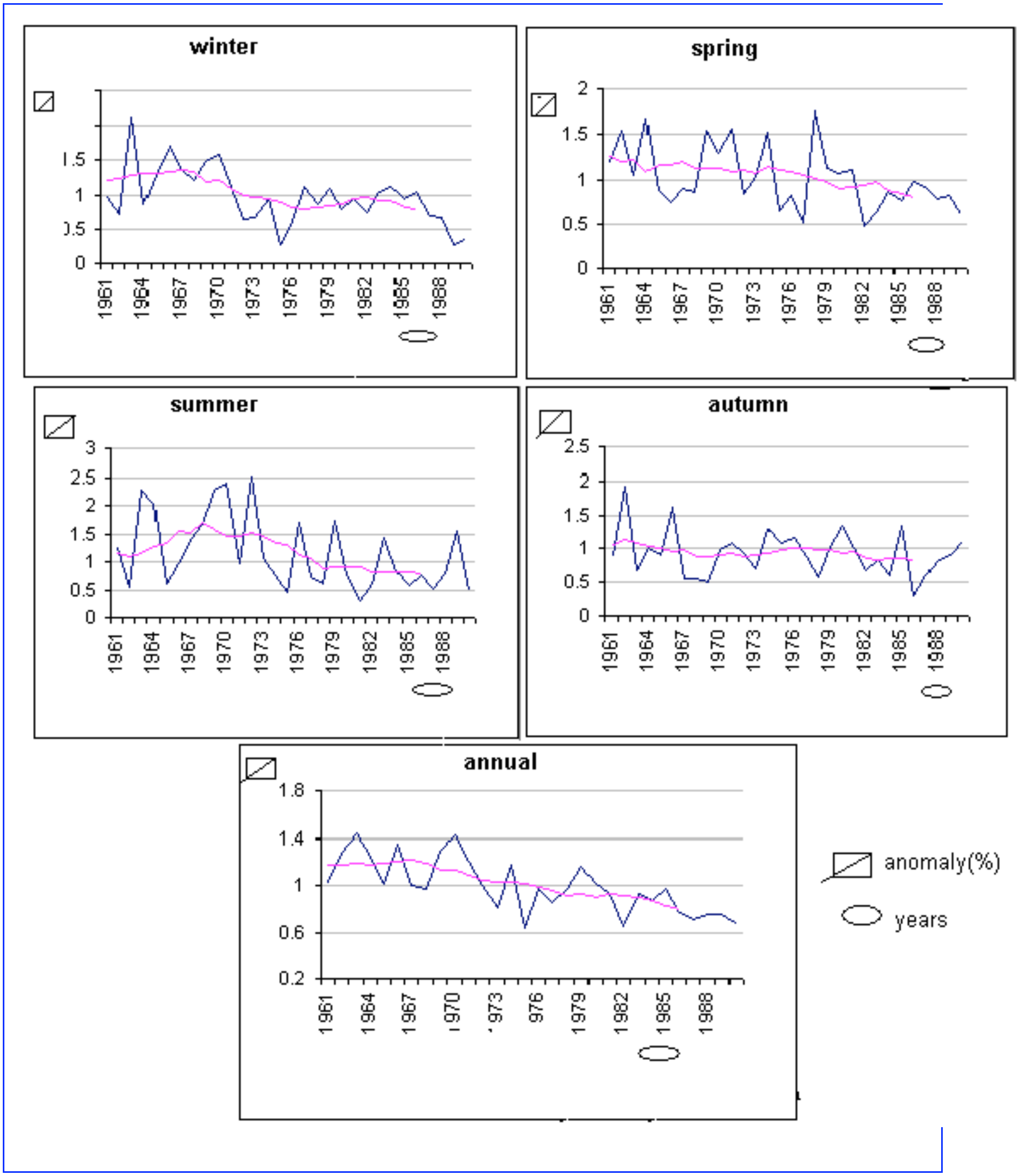


Fig.3 Air temperature seasonal and annual anomaly in Tirana (1961-1990)

Please note: the blue line shows the anomaly (%) the pink line shows air temperature average

3.2.2 Rainfall

Total annual rainfall over the whole Albanian territory is 1485 mm although spatial distribution of the rainfall varies greatly. The lowest value is registered in the south-eastern part of the country (600 mm) followed by Myzeqe Field with 1000 mm. The biggest rainfall value is registered in the Albanian Alps at 2800-3000 mm. Another zone with high rainfall levels is the south - western zone with 2200 mm.

Rainfall shows a clear picture of the annual climate pattern, reaching the maximum in winter and the minimum in summer. The highest level of rainfall is recorded during cold months (October – March), about 75% of the total. The wettest month is November and the driest is July and August (Fig.5). The number of rainy days (>1.0mm) in the whole territory varies from 80-120 days/year. The spatial distribution of this index follows that of the rainfall (Fig.5). Almost 78% of rainy days are recorded during the cold period.
Fig.4 shows annual rainfall anomalies, 10 years skewed means of anomalies for Tirana station. The figure and a detailed analysis, carried out for the rest of the stations, show that generally annual rainfall quantity has a minor negative tendency. This is due to a decreasing quantity of rainfall during spring and winter. Shkodra and Vlora make an exception showing a positive tendency of the rainfall. Meanwhile Tirana, Korca and Kukesi stations, have a very minor negative tendency.
Generally there is a negative tendency of rainfall. Rainfall decrease each year with a trend of 0.7% from 1961 to 1990. There is also a minor positive tendency but very insignificant in the north, the area of Albanian Alps.

3.2.3 Wind

Wind directions depend on the distributions of the pressure gradients and the local topography. Considering the annual frequency of winds, northern winds predominate usually on the seacoast, but the direction changes inland. In January (month with the highest wind circulation frequency) winds enter from inland to the seacoast changing directions due to the orientation of the valley where the station is situated. In the stations of Shkodra and Vlora predominate eastern winds, in Tirana the most frequent direction is south- east, and in Kukes it is the north-eastern direction.

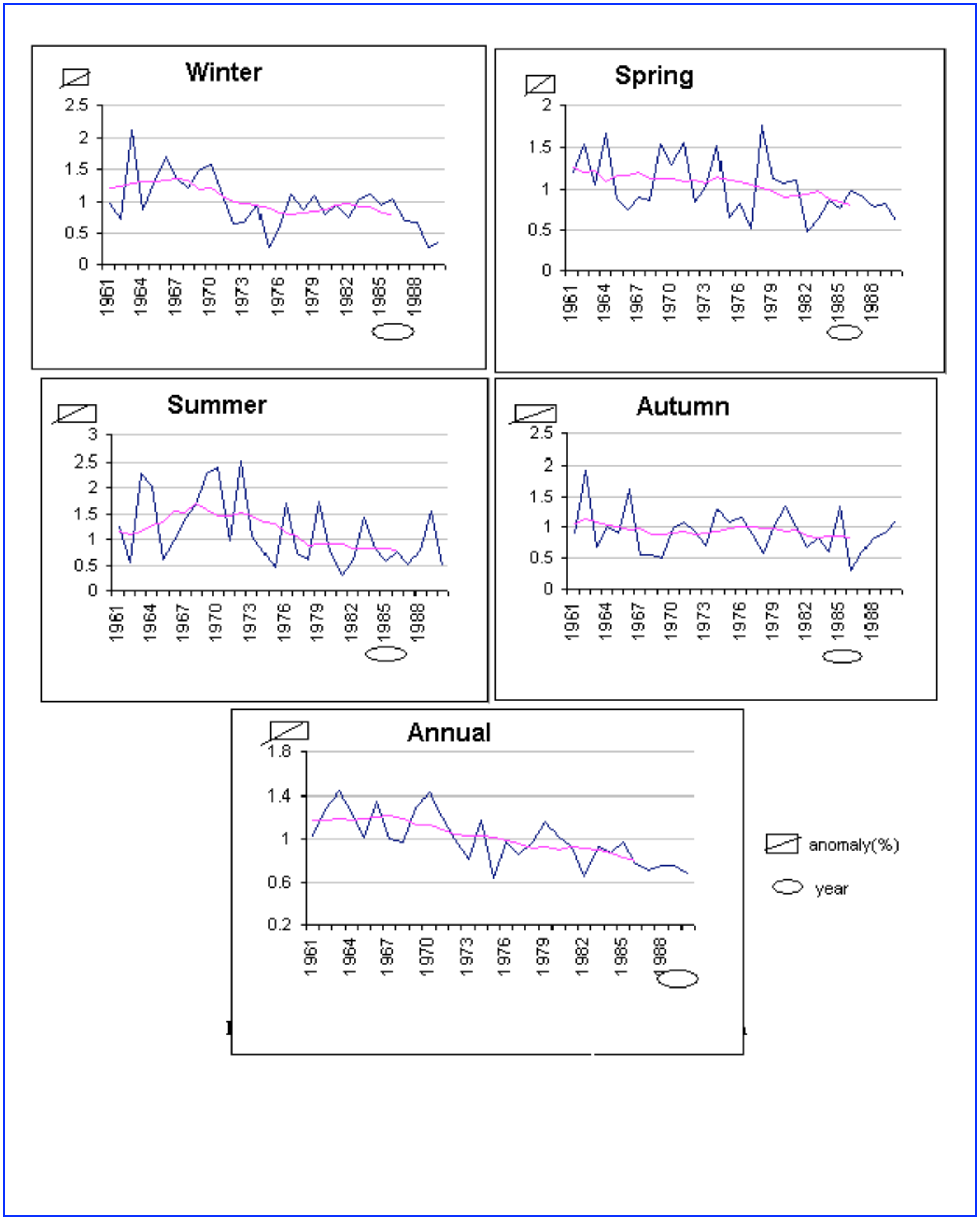


Fig. 4 Seasonal and annual anomaly of precipitations for Tirana (1961-1990)

Please Note: blue line- anomaly, pink line – precipitation average

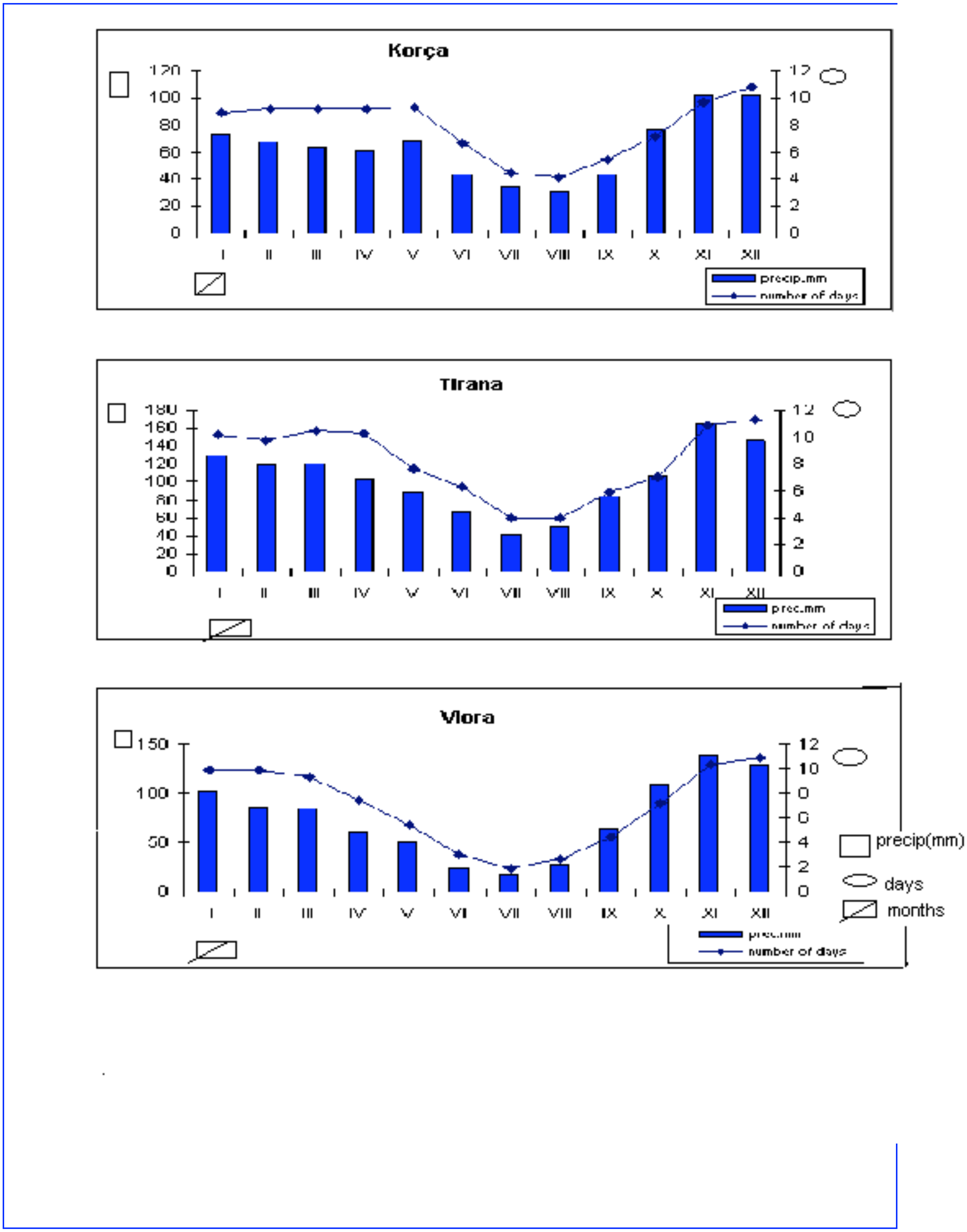


Fig. 5 Distribution of annual precipitations and number of days with the precipitation

- ➢ 10mm in three different cities in Albania from 1960-1990 (Vlora- south, Korca- south)

3.3 The study area

3.3.1 Location area for Tirana city

The study area for pollen analysis is based in Tirana, which is situated on the east of Dajti Mountain and on the west 30 km to the Adriatic sea (Fig.6). The census in 2002 showed that the district of Tirana has 627,204 inhabitants. The Tirana region has seen a population increase of 30% due to internal migration mainly from rural areas in the north.

The study area is a typical dense urban area. There are no taller buildings in the immediate vicinity of the place where the trap was placed.

The pollen collection was performed by a Burkard Volumetric 7-day Spore Trap [Burkard, 2001].

The trap was placed on the flat roof 15m above the ground level at the University Hospital Centre in Tirana for the study years (1995,1996, 1998, 2002, 2003, 2004) in the east side of the city. A full description of the methodology is given in chapter 4.

Meteorological data were obtained from the Meteorological Institute of Tirana, which is situated 5 km away from the sampling place.

Tirana has a maritime Mediterranean climate, with hot, dry summers and mild winters. The annual average temperature is 15° C, in January 17°C and in July 28°C. Generally, it ranges from 17-31°C in July, to 2-21°C in January. The average precipitation is 1247mm, 70% of it in the cold half part of the year.

Generally the Tirana plain is surrounded by low hills, except on the east where there is the Dajti mountain (1612m). It keeps the city protected from cold winds from the east in wintertime and produces downslope during summer nights.

3.3.2 Topography

Tirana city with geographical data: latitude: 41° 19' 39N and longitude: 19° 49' 8E is bordered by low hills in the South, average height of 300m above sea level, in the North by the Tirana river, in the East by Dajti mountain, height 1612 m and in the West by lowland areas descending towards the Adriatic sea (about 35 km air line).

The average altitude of the city is about 110 m above sea level. Tirana lies on relatively flat ground but sloping East-West.

This figure, showing an aerial photograph of Tirana with the site of monitoring, has been removed due to 3rd party copyright. The full unedited version of the thesis may be consulted at the Lanchester library, Coventry University.

Fig. 6 Air photograph of Tirana

This figure, showing a street map of Tirana with the site of monitoring, has been removed due to 3rd party copyright. The full unedited version of the thesis may be consulted at the Lanchester library, Coventry University.

a)

This figure, showing a regional map of Tirana and the surrounding area, has been removed due to 3rd party copyright. The full unedited version of the thesis may be consulted at the Lanchester library, Coventry University.

b

Fig. 7 Two different topographic maps: a) street map b) region map

3.3.3 Albanian flora and urban environment

Albania has a rich diversity of flora with about 3200 vascular flora species. Approximately 30% of the European flora occurs in Albania.

There are 27 plant species with 150 subspecies, which are endemic in Albania.

Since 1990, the post-communist period, the great demographic increase of urban zones following the political changes resulted in the enlargement of urbanized areas and the deterioration of the environment, by destroying green areas in particular. Green areas in cities such Tirana suffered because of illegal constructions, but the most damaged sites are the central park and the banks of Lana River in Tirana.

It is estimated that in the capital city of Tirana, the green surface area has been reduced from 12.5m^2/inhabitant to 5m^2/inhabitant.

3.3.4 Pollen sources

The vegetation around the Tirana area, at least at a level of 5-600m above the sea level, is dominated flora of the maquis type with small amount of shrubs.

The surrounding hills are generally dominated by:

Carpinus orientalis, Colutea arborescens, Juniperus oxycedrus and Juniperus communis.

Local sources are comprised of different vegetation types: parkland and gardens, trees planted along transport routes and around Mountain Dajti (4 km away), trees and plants within the sampling area.

The small parks around the sampling area consist of mixed trees and grassland. The trees that predominate are: Acer negundo, Aesculus hippocastanum, Pinus maritima, P.halepensis, Cedrus deodora, Acacia dealbata, Platanus orientalis, Quercus ilex, Ligustrum vulgare, Ligustrum lucidum, Rosa sp, Tilia tomentosa, Prunus spp and several others.

The most predominant sources of pollen are from the regions of the of Dajti mountain which going to the high level has the following types of vegetation:

1. Maquis type (600-700m)

This type of vegetation is characteristic of the Mediterranean region. The main elements are: Arbutus unedo, Erica arborea, Myrtus communis, Viburnum tinus. The most common association is Arbutus unedo- Erica arborea

In this type the grass family predominates with different species.

2.Quercus type (to 900m)

The Quercus type is found at altitudes up to the maquis type with the most common Quercus cerris and Quercus frainetto. As the result of damaging this zone now is now replaced by shrubs with Carpinus orientalis, Quercus ilex, Fraxinus ornus, Juniperus oxycedrus, Juniperus communis, Cornus mas as well some grass species.

2. Fagus type (from 900m to 1612m)

It is well conserved as it was under the state protection. It consists of an old forest with Fagus sylvatica, Acer pseudoplatanus, Ostrya carpinifolia, Abies alba, Quercus cerris and small amounts of Pinus leucodermis and Pinus nigra.

The grass species are rare in this vegetation type.

Also there are a lot of trees and shrubs planted on the area of University Hospital Center of Tirana where the trap was placed. Among them are: Cupressus sempervirens, Pinus halepensis, Pinus maritima, Tilia spp , Quercus ilex, Olea europea, Ligustrum vulgare, Hedera helix, Ulmus sp and Thuja orientalis. There are grasslands on this area (1ha), which produce a notable amount of grass pollen.

CHAPTER FOUR
METHODOLOGY AND POLLEN CALENDAR

4.1 Sampling

Pollen data was collected by a Burkard volumetric spore trap of the Hirst design [Hirst, 1952]. The pollen trap was placed on the flat roof 15 m above the ground level at the University Hospital Center in Tirana for the study years (1995, 1996, 1998, 2002, 2003, 2004) in the east side of the city (fig 6). The place where the trap was placed is an open space with no nearby buildings, which could interrupt the movement of the air. A full description of the site is given in section 3.3.

The Burkard trap sucks air into the trap at a rate of 10 l/min through a standard orifice (2mm x 14 mm). Particles are impacted on adhesive material (paraffin oil, toluene, and Vaseline) and the drum tape coated with the adhesive material was changed once a week at 09.00 in the morning. The tape was cut into 7 pieces each of a length of 48 mm corresponding to a 24 hours sampling which correspond to the seven days of the week. The microscope examination was under the method described by Kapyla & Penttinen [1981] that consists in reading 12 vertical transverses. The results were expressed as the number of pollen grains per cubic meter of the air and given as daily average values.

The standard sampling procedures proposed by the British Aerobiology Federation [BAF, 1995] were employed.

The daily weather data for temperature (maximum, minimum) and rainfall for the study period has been obtained from the Meteorological Institute in Tirana. The location of this is given in section 3.3. It is known that it is desirable to have other meteorological data such as humidity and wind speed but the use of these data is related to their availability in Tirana for the study period. Later on it was possible to obtain wind data from the airport of Tirana which is 40 km away from the location of the pollen trap. The wind data were used as possible variables for forecast models. The humidity is auto correlated with temperature and rainfall and is not forecast regularly in Tirana so cannot be used for pollen forecasting. It also should be noted that in the Tirana weather forecast the wind is often given as direction rather than its speed.

4.2 Data transformation

Daily average pollen counts were normalised to allow direct comparison betweens seasons using the work from different authors [Moseholm *et al.*, 1987; Toro *et al.*, 1998]. The authors have found that an equation obtained from the data transformed by square root usually resulted in a better prediction, because substantial errors can be introduced in de- transforming the data to the usual scale (pollen grains/m^3), although its R^2 value was lower than equations obtained with other transformations.
To study the features of the pollen season, the pollen count days are often referred to as the number of days starting from the 1^{st} of January.

Also the daily average pollen counts were presented as 10-day running means in order to compile a Pollen calendar for Tirana. The presentation of the pollen count data in this form for the pollen calendar was made according the technique by Stix and Ferretti, 1974. Further description for this can be found in section 4.3.1.

The principal pollination period was divided into three phases for Grass and Urticaceae (pre-peak, peak, post-peak) since the behaviour of the pollen seasonal curve differs according to these phases. Olea pollen season was divided into phases, pre and post peak due to its shorter presence in the air (no more than 45 days). A further description on how these phases are divided is explained on section 4.4 Tirana pollen season. The whole pollination period was not considered as one entity since the pre, peak and post-peak were seen to differ.

A number of variables were examined for possible inclusion in the linear regression analysis for long-tem forecast models and the ones with the highest correlations will be included in the model. The variables were selected after reviewing studies on the effects of meteorological variables on the Grass, Olea, Urticaceae pollens made by different authors.
Among such variables were included the 10 day means of daily rainfall, maximum temperature, minimum temperature for each month starting from January until May, 30

day means, accumulated temperature, accumulated temperature above 5.5C etc. It was calculated that 150 different weather parameters combinations were entered for simple linear regression. Later, only the parameters with high correlation were used for entering into the model.

The variability of using 5 day, 4 day, 3 day and 2 day running means of daily pollen counts was also explored. It has been found that pollen concentration can drop after successive high counts, a phenomenon explained by the fact that most of the available pollen has been released from the anthers of pollinating plants during the initial period of dry weather.

Further explanation of specific methodologies will be given in the relevant sections together with the analyses of the data and development of methods.

4.3 The pollen calendar in Albania

The registration of pollen concentrations in the air started in Albania in the year 1995. Before this date no pollen monitoring had been done in this country.

A Burkard volumetric trap was placed on the roof of the University Hospital Center of Tirana at a height of 15 metres. Starting from the year 2002, two additional traps were installed in two other cities, Lezha (northwest) and Vlora (southwest).

Due to technical problems running the trap, unfortunately there are some years with missing data. It should be noted that through those years Albania was in a difficult economic situation and it experienced a lack of electricity that affected the trap motor. The missing data are from the years of 1997, 1999, 2000 and 2001.

The selection of the 15 taxa including eight prescribed taxa selected was on the basis of either their abundant airborne occurrence and/ or their allergenic significance (Table.1) and seven additional taxa selected from ten allergenically less important, or aerobiologically less frequent taxa [Spieksma, 1991].

As a perequisite for building pollen forecast models it was necessary to determine the main pollen types in the air of Tirana and to gain knowledge of their pollen seasons. For this reason the basic methodology included the construction a pollen calendar for the area.

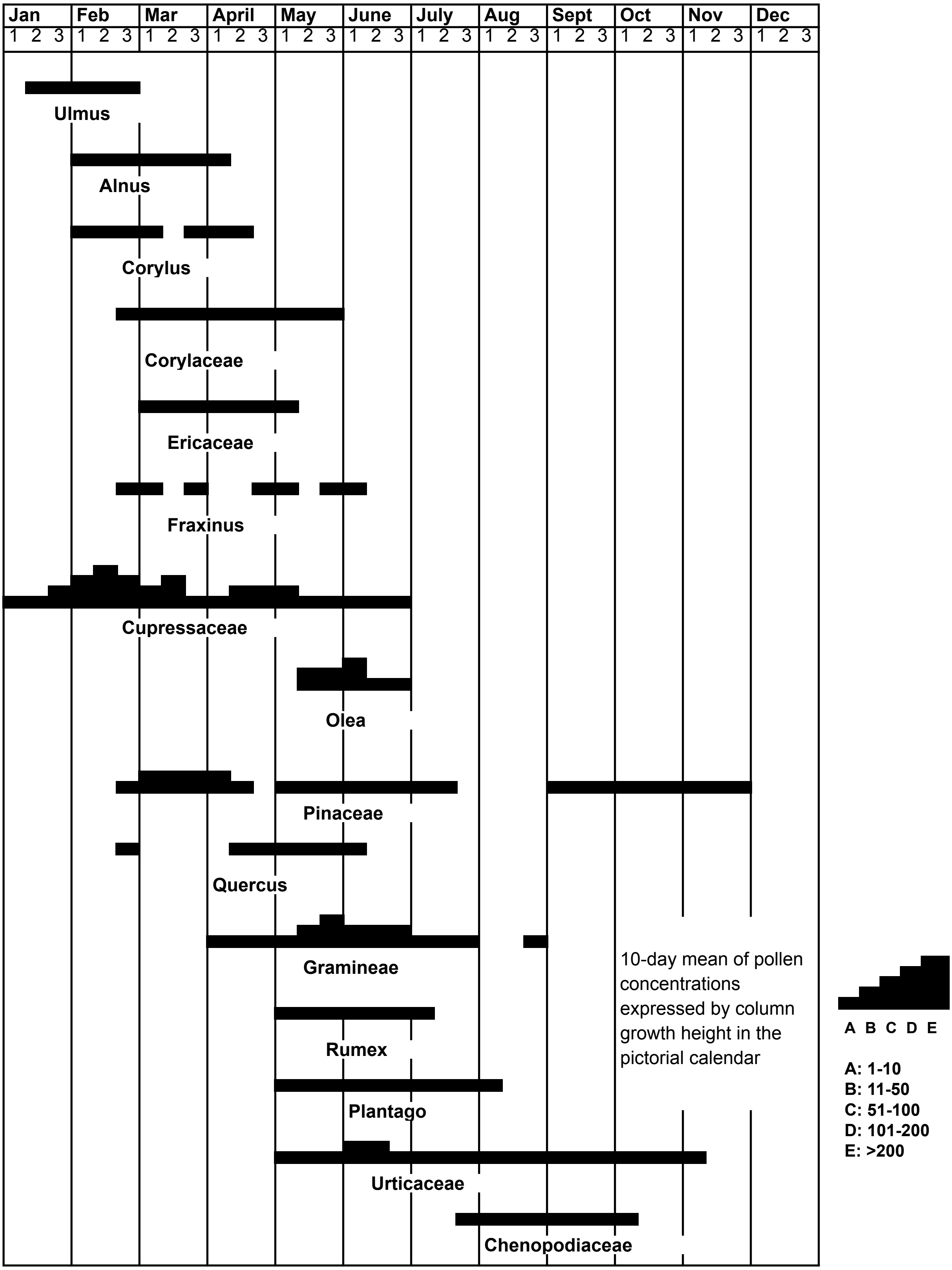
4.3.1 Evaluation and presentation of the data for the pollen calendar

For the presentation of the pollen count data in the form of a pollen calendar, it was decided to adopt the technique according to Stix and Ferreti, [1974].

In this method, daily pollen counts of ten-day periods are summed, and averaged over the study years. Subsequently, these average sums are placed in exponential classes, which are depicted by column growth heights in the pictorial calendar [Fig.8]. By this technique, the general course of airborne presence and timing of the peak values become clearly visible and in the long term vision easy comparable with other aerobiological stations. Also the use of ten day periods of average pollen concentrations allows data to be presented as smoothed curves and eliminates the effect of short term variations in weather or conditions. The calendars then allow comparison of the individual years for variation in both the timing of the start and duration of pollen seasons as well as pollen abundance.

Table.1 The 15 taxa selected in flowering order, according to the most frequently occurring genera and species

1. Ulmus	Mostly U.campestris
2. Alnus	Mostly, A.glutinosa, A.incana
3. Corylus	Mostly C.avellana
4. Corylaceae	Including Carpinaceae
5. Ericaceae	Including Erica arborea, Arbutus unedo
6. Fraxinus	Including F.ornus, F.excelsior, F.angustifolia
7. Cupressaceae	Including Cupressus, Chamaecyparis, Juniperus, Taxaceae
8. Olea	Including O.europea, O.oleaster
9. Pinaceae	Including Pinus, Picea, Abies, Cedrus,
10. Quercus	Mostly Q.robur, Q.ilex, Q.rubra, Q.cerris
11. Graminaeae	Mainly wild grasses
12. Rumex	Mostly R.acetosa, R.crispus
13. Plantago	Mostly P.lanceolata, P.major, P.coronopus
14. Urticaceae	Mostly U.dioica, Parietaria officinalis, P.diffusa
15.Chenopodiaceae	Including Amaranthus



Pollen calendar for Tirana during the years of 1995,1996,1998,2002

	1995			1996			1998			2002		
Taxa included in the pollen calendar	**Peak day**	**Season sum**	**%**	**Peak day**	**Season sum**	**%**	**Peak day**	**Season sum**	**%**	**Peak day**	**Season sum**	**%**
Ulmus	44	56	0.6	35	133	0.9	13	60	0.4	23	69	0.9
Alnus	57	82	0.8	98	292	2.0	52	250	1.6	59	38	0.5
Corylus	42	109	1.1	98	206	1.4	52	302	1.9	50	82	1.1
Corylaceae	120	438	4.5	57	262	1.8	115	338	2.2	92	60	0.8
Ericaceae	87	69	0.7	94	439	3.1	69	221	1.4	81	148	2.0
Fraxinus	152	84	0.9	128	48	0.3	83	252	1.6	104	38	0.5
Cupressaceae	59	2559	26.5	74	5610	39.1	57	8379	53.4	61	2185	28.9
Olea	153	2088	21.6	149	1059	7.4	143	1717	10.9	139	732	9.7
Pinaceae	88	792	8.2	90	1310	9.1	65	1366	8.3	78	1184	15.6
Quercus	128	96	1.0	129	235	1.6	118	91	0.6	129	136	1.8
Gramineae	141	1118	11.6	147	2452	17.1	142	1574	10.0	138	1551	20.5
Rumex	136	111	1.1	163	281	2.0	142	94	0.6	174	120	1.6
Plantago	157	260	2.7	163	250	1.7	167	207	1.3	226	408	5.4
Urticaceae	201	1754	18.1	154	1638	11.4	147	741	4.7	174	792	10.5
Chenopodiaceae	224	57	0.6	231	116	0.8	248	161	1.0	266	25	0.3

Table.2 Peak day, Total pollen count, and Percentage for the years 1995, 1996, 1998, and 2002 in Tirana for 15 taxa according to their flowering period.

4.3.2 Graminaeae

Pollen from the grass family (Poaceae) is considered to be one of the most important aeroallergens in Europe. This is because of its ubiquitous nature and the allergenic capacity of pollen grains from its species. Poaceae is a highly adaptable and extremely large family that is widely distributed.
In Albania this family is widespread in almost all the regions of the country with about 50 genera and 126 species.

Grass pollen allergy is the most common allergy in Europe. Twenty per cent of allergic patients in Denmark suffer from grass pollen allergy. In Holland and France, 80% of allergic patients suffer from grass pollen allergies. Also in Italy more than 60% of pollinosis patients are grass-pollen sensitised [D'Amato *et al.*, 1991, a].

Appendix A (1 a – d) shows the daily graphical variations of grass pollen in 4 years study and clearly the multiple peaks caused by the flowering of different grass pollen from the beginning to the end of the season.

There are differences in the yearly total pollen counts with the lowest one in 1995 with 1118 grass pollen grains and the highest one in 1998 with 2452 grains.
The difference in the timing of the peak day was 8 days within the study years with the earliest one in year 2002 and the latest one in 1996. The pollen concentration during the peak day were high was an average of 100p/m^3.

Grass pollen occurred from March until September with two months between with very high pollen counts respectively in May and June. In all the study years May was the month with the highest pollen concentrations recorded. The amount of pollen collected ranged between 10 and 20.5% of the annual total with the year 2002 being the highest.

4.3.3. Cupressaceae

The Cupressaceae family is widely distributed in Albania with three genera and eight species. The principal genera are Juniperus, Cupressus and Thuja.
Cupressaceae allergy appears to be a new aspect of pollinosis in some Mediaterranean areas. Cupressaceae pollen has been cited by different authors as an important allergen in the Mediterranean region [Caiaffa *et al.*, 1998, D'Amato and Liccardi., 1994].There are Cupressaceae species with a low allergenic capacity, but cases have been reported of cross reactivity with some Pinaceae [Pettyjohn & Levetin, 1997] and Taxodiaceae species [Crosta *et al.*, 1996].

Appendix A (4 a- d) shows the daily variations of this family over the four years. The maximum values of 8379 pollen grains were recorded in 1998, followed by 1996 with 5610 grains. The percentage of Cupressaceae pollen with regard to the annual total oscillated between 26.5% in 1995 and 53.5% in 1998.
The Cupressaceae pollen was present in the atmosphere, to a greater or lesser degree, during the entire period under the study (December to January), except for five months (Aug-Dec) in 1995 and two months in 2002 (Oct-Nov).
The highest values were recorded in February, March and April.
The timing of the peak day in four years shows a difference of 13 days and the pollen concentrations on that day were extremely high with about 1000p/m^3 as a average except in 1995 in which the peak value reached only 180p/m^3.
Appendix A (4 a-d) shows different peaks of the pollen counts of this family possibly due to the contribution of the three genera in it.

4.3.4. Urticaceae

In Albania, the Urticaceae family is composed of two genera, Urtica (four species) and Parietaria (two species). Since the microscopic analysis of Urtica and Parietaria pollen grains does not allow them to be distinguished, in spite of differences in size, and considering the fact that the pollen seasons of Parietaria and Urtica dioica overlap or coincide, it is preferable to quote counts of atmospheric pollen as Urticaceae without attempting to discriminate between genera or species.

It is well established that Parietaria pollen is the most allergenic [Bousquet *et al.*, 1986], and that the other species of Urticaceae are very rarely responsible for the occurrence of clinical symptoms, as there must be a lack of cross allergenicity [Bousquet *et al.*, 1986].

The Urticaceae pollen in Tirana constituted between the third and fourth important number of pollen over the study years with a percentage that varied from 4.7% in 1998 as the lowest one to 18.1% in 1995 as the highest one.

The Urticaceae pollen release period is a long one starting from April and lasting until November. The months with most abundant pollen were those from May until September.

The total pollen counts have reached high levels in two years respectively in 1995, 1754 nettle pollen grains and in 1996, 1638 grains with a difference of low levels in two other years with 741p/m^3 in 1998 and 792p/m^3 in 2002.

Also the peak days vary between the four years having the earlier one in 1998 in day 147 and the latest one in 1995 in day 201.The day peak value did not reach high counts and was counted a peak value as an average of 42 p/m^3.

The Urticaceae pollen persists for a long time in the air, but with not very high values. There are two pollination periods in this family, one in early spring and the other one in autumn (*Appendix A* 3 a-d).

4.3.5 Olea

The olive tree Olea europapaea L. belongs to the Oleaceae family and is one of the most characteristic features of Mediterranean flora. In Albania Olea is constituted of two species: O. oleaster and O. europaea.

The olive pollen has been recognised as one of the most important allergenic pollens in the Mediterranean areas, where olive pollinosis is a widespread form of respiratory allergic disease [Dominguez-Vilches *et al.*, 1993, D'Amato and Liccardi, 1994].

The Olea pollination season lasts from May till June reaching very high pollen concentrations (*Appendix A* 2 a-d). It has a short pollen period but with high counts reaching in peak days to a maximum of a 250 p/m^3. The difference in peak days for four years was 14 days with the earliest one in 2002 in day 139 and the latest on in 1995 in day 153.

It was noted that the Olea total pollen counts have two years with high values respectively in 1995, and in 1998 (Table.2) and two years with low totals respectively in 1996 and in 1995.
As the *Appendix A* (2 a- d) shows there are two different peaks in the Olea pollination season with the first peak at about the end of May and the second peak in approximately ten days after the first one. The Olea pattern is slightly different in 1995 compared with three other years.

4.3.6 The Pinaceae family

The Pinaceae family in Albania consists of four genera and 17 species. The most important genera are Pinus, Abies, Piceae, Cedrus.
Although the Pinaceae family contributes to the pollen calendar with the high pollen values, the allergy cases resulting from this family are very rare.

The pollen from this taxon is present in the air for most of the year with the exception of three months in 1995 (Aug-Oct) and two months in 1996 (Jan-Feb).
The total pollen sum of this family registered high and low sums with the highest one in 1998 with 1366 Pinaceae pollen grains and the lowest one in 1995 with 792 total pollen sum.
The months with the high pollen concentrations were March, April, May and June.
The pollen curve of this family is very long with different pollen peaks probably because there are many species contributing to it.
The highest peak during the four years under the study occurs in the month of March with a difference of 25 days between those years (*Appendix A* 5 a-d). The earliest one occurred in day 65 in 1998 (6/3) and the latest one in day 90 in 1996 (30/3).
The Pinaceae family contributes to the pollen calendar with a percentage that varies between 8.2% in 1995 to 15.6% in 2002.

4.3.7 Quercus

Quercus (Oak) belongs to the Fagaceae family together with such taxa as Fagus and Castanea.There are 11 species belonging to the Quercus genus in Albania, all of which are anemophilous trees and shrubs widely distributed throughout the climatic zones of the country.

Although it is assumed that European Quercus pollen has a low allergenic effect, allergic sensitisation has yet to be fully clarified. Recent studies consider this pollen type responsible for some cases of allergy in areas with abundant Quercus vegetation [Subiza *et al.*, 1987; Negrini and Arobba, 1992].

Quercus pollen types in Tirana contributed to the pollen calendar with no more than 1.8% during the four years.This percentage varied over the years.

Also the total pollen sum from this genera did not reach high values. The highest total sum was registered in the year 1996 with 236 oak pollen grains and the lowest one in 1997 with 91 pollen grains.

The difference in the timing of the peak day among the four years was only 11 days.

The pollen of Quercus is present in the atmosphere only during two months, namely April and May (*Appendix A* 6 a-d). Only in the year 2002 was this pollen type found in more than two months (February-March) besides April and May.

4.3.8 Corylaceae

The Corylaceae family is composed of Corylus, Carpinaceae with five species in it.

As Corylus type pollen is easily distinguished from other genera of the Corylaceae family it was decided to separate the Corylus pollen type from the two other genera.

It is well known that Corylaceae pollen can cause allergic respiratory symptoms in sensitised subjects, particularly in the northern areas of Europe [Eriksson *et al.*, 1984]. Studies from Italy have shown that individuals allergic to Ostrya pollen are also allergic to other Corylaceae and Betulaceae pollen suggesting cross-reactivity among them [Patriarca *et al.*, 1998].

The Corylaceae presented in the pollen calendar contributed with a percentage, which varied from 4.5% in 1995 to 0.8% in 2002. The highest total pollen sum from this family was registered in the year 1995 with 438 Corylaceae pollen grains and the lowest total sum was registered in year 2002 with only 60 Corylaceae pollen grains.

Appendix A (7 a- d) shows that there are three different species contributing to the Corylaceae pollen curve in the four years of study.

The timing of the peak day varied a lot with the earliest one in day 57 in 1996 (26/2) and the latest one in day 120 in 1995(30/4). This possibly could be explained with the different species contributing to the pollen curve of this family.
The Corylaceae pollen is present from February till May with the highest pollen counts recorded in April.

4.3.9 Ericaceae

The Ericaceae family in Albania is composed of 6 genera and 13 species.
Among the important genera are Erica and Arbutus, which were taken into consideration when compiling the pollen calendar. There is no documented evidence on the allergic reaction from this family.
The relative amount of pollen collected ranged between 0.7% in 1995 and 3.1% in 1996. The Ericaceae pollen was present in the air from February until May although the highest pollen concentrations from this family were registered in March and April.
The difference in the timing of the peak day was 25 days with the earliest in 1998 in day 69 (10/3) and the latest in 1996 in day 94 (3/4). Also the pollen concentrations on the peak day did not reach high levels recording the highest one in 1996 with 78p/m^3.
Appendix A (8 a-d) shows that in the Ericaceae pollination curve there are three different peaks. This is probably caused by contribution from three different species. In all four years the second peak was highest.

4.3.10 Fraxinus

The genus Fraxinus belongs to the Oleaceae family and is composed in Albania of three species namely as Fraxinus ornus L, Fraxinus excelsior L and Fraxinus angustifolia.
It is known that Fraxinus is not considered to be a highly allergenic species but there is a high degree of cross-reactivity among the Oleaceae family [Bousquet *et al.*, 1986]. Some studies have suggested that in France and Switzerland the ash tree (Fraxinus excelsior) is a strongly allergenic species [Peeters A., 1994]. Conversely some studies, for example in Poland, show that there are no cases of allergy reported in relation to this genus [Rudzki E., 1998].

In the pollen calendar of Tirana, Fraxinus does not represent a high percentage. It contributes with a range of percentage that goes from 0.5% in 2002 to 1.6% in 1998.
The Fraxinus pollen is present in the air from February till May, except in the year 1995 when pollen from this family was found even in June (*Appendix A* 9 a-d). Also the monthly total sum from this taxa varied between the years. In 1995 the highest pollen concentrations of Fraxinus were found in May whereas in 1996 and 2002 they were found in April and in 1998 in March. The difference in the timing of peak days was 69 days. This could possibly be explained by three different species participating in the pollen curve.

4.3.11 Corylus

The genus Corylus belongs to the Corylaceae family and in Albania there are only two species from this genera: Corylus avellana and Corylus colurna.
Corylus is a winter-pollinated tree. The pollen is present in the air from January until April with the exception of two years (1998 and 2002) where the pollen curve of this family was shorter from January until March (*Appendix A* 10 a-d).
The relative amount of pollen collected from this taxon ranged between 1.1% in 1995 and 2002 to 1.9% in 1998.
The difference in the timing of the peak day was 56 days with the earliest in 1995 in day 42 (11/2) and the latest in 1996 in 98 (7/4). Also the pollen concentrations on the peak day did not reach high counts with the highest was registered in year 1995 with 65p/m^3 in the peak day.

4.3.12 Alnus

The genus Alnus is placed in the family Betulaceae, together with the genus Betula (Birch). This is an even more important allergen but it is not present in the Tirana vegetation. Alnus is a rather common, deciduous tree typically wind-pollinating. Alder trees shed large quantities of tetra or pentaporate pollen grains in early spring. In Albania Alnus has two species: A.glutinosa and A.incana. Alnus is the winter pollination pollen type present in the air from January until April.
Except in the year 1995 when Alnus begin to pollinate in January, the pollen of Alnus in other years started in February.

It should be noted that the year 2002 was exceptional for the pollen curve of Alnus as it was found only in the month of February.
The difference in the timing of the peak day was 46 days with the earliest in day 52 (21/2) in 1998 and the latest in day 98 (7/4) in 1996.
The pollen concentrations in the peak day did not reach high concentrations, the highest one was in 1996 with 48p/m3 in the peak day.
The relative amount of pollen collected ranged between 0.8% in 1995 to 2% in 1996 (*Appendix A* 11 a-d)

4.3.12 Rumex

Rumex (Sorrel) belongs to the Polygonaceae family together three other genera.
The Rumex genus in Albania includes 20 different species. The clinical relevance of this genus can not be defined easily.
There are studies regarding the allergy from Rumex for example by Horak *et al.*, [1979], when the sensitivity to sorrel was expected in 20% of patients with hay fever in combination with allergy to weeds. This lead to the hypothesis that a possible simultaneous allergy to sorrel should be considered in cases of allergy to grasses and/or weeds. In the pollen calendar, Rumex contributed with relative amounts of pollen collected from 0/6% in 1998 to 2% in 1996. The difference in the timing of the peak day was 38 days with the earliest in day 136 (16/5) in 1995 and the latest in day 174 (23/6) in 2002. The pollen was present in the air from April until July with the highest pollen counts in June (*Appendix A* 12 a-d).

4.3.14 Plantago (Plantain)

The genus Plantago belongs to the Plantaginaceae family and consists of 18 different species. The commonest species are P.lanceolata and P.major. There are various different studies regarding the clinical relevance of Plantago [Merret *et al.*, 1980; D'Amato *et al.*, 1989; Charpin *et al.*, 1962].
Comparing different studies on this genus, it seems that Plantago pollen is of greater importance in Montpellier than some other parts of Europe as [Bouesquet *et al.*, 1986] reported. Plantago is present in the air from April until September contributing to the

total pollen collected at a range from 1.3% in 1998 to 5.4% in 2002 (*Appendix A* 13 a-d)

Also the difference in the timing of the peak day was 10 days with the earliest in day 157 (6/6) in 1995 to the latest in day 167 (26/7) in 1998.

The yearly total pollen recorded was highest in 2002 with 408 grains compared with the lowest in 1998 with 207 grains.

4.3.15 Chenopodiaceae

Chenopods are plants with a widespread distribution and in some cases are of major importance in inducing seasonal allergic disease. From the taxonomic point of view they belong to the suborder Chenopodiinae which is composed of two related families Chenopodiaceae and Amaranthaceae.

The pollen grains of these families are very similar, and they are generally described together in aerobiological studies [Lombardero *et al.*, 1985]. This approach was taken in the current study.

The Chenopodiaceae family in Albania is composed of 14 genera and 36 species. Among the most important genera are those of Chenopodium, Salsola and Beta.

It was reported that if even when Chenopodium produces relatively small amounts of pollen, its abundance in some areas could concentrate enough pollen in the air to cause hay fever [Homan, 1963]. Other studies have shown that Salsola Kali has been considered the major weed pollen responsible for hay fever in Iran [Shafiee.A., 1976], an important cause of allergic rhinitis in western USA [Newmark, F.M., 1978] and in south Europe [Ferrara, T *et al.*, 1989]. There is a high degree of cross-reactivity between the Chenopodiaceae and Amaranthaceae family and this fact was recognized very early.

Pollen grains of Chenopodiaceae/Amaranthaceae family are present in the air from May until October (*Appendix A* 14 a-d). They do not release large amounts of pollen reaching relative amount of pollen collected from 0.6% in 1995 to 1% in 1998.

The difference in the timing of the peak day was 42 days with the earliest in day 224 (12/8) in 1995 and the latest in day 248 (5/9) in 1998.

August and September were the months where the highest pollen concentrations were recorded.

4.3.16 Ulmus

The genus Ulmus belongs to the Ulmaceae family and is composed of three species in Albania. It is a very early pollen type found in atmosphere. There is no documented evidence for the allergic sensitisation from this genus.

Ulmus was the first pollen found in the air from January until March. The highest concentrations were in February and March in all the four years of the study (*Appendix A* 15 a-d).

It contributed to the amount of pollen collected at a range from 0.6% in 1995 to 0.9 in 1996 and 2002.

The difference in the timing of the peak day was 34 days with the earliest in day 13 (13/1) in 1998 and the latest in day 44 (13/2) in 1995.

The highest total pollen sum recorded was in year 1996 with 133 grains and the lowest in year 1995 with only 44 grains.

4.4 Defining the pollen seasons

In the literature review (chapter two) the main approaches to defying the start, peak and end of the pollen seasons were discussed together with the reasons why it is necessary to do this. This information was applied to the particular features of the data obtained for this study and relevant methodology was adapted to suit the Tirana pollen seasons.

It was decided to calculate the start of Olea pollen season for each year by using the "Threshold 1" method. The start of Olea pollen season was defined as the date on which 1 pollen grain/m^3 daily average was recorded as long as 1 or more pollen grains/m^3 were subsequently recorded on 5 consecutive days [Galan *et al.* 2001, a]. The end of the season was defined as last day with five consecutive days with pollen concentrations reaching no more than 1 pollen/m^3. Also it was decided to use more methods for the other two taxa, grass and Urticaceae. Firstly, three methods for defining the pollen season were used: "Threshold 30" method, 2.5% method and 5% method.

With "Threshold 30", the start and the end of the grass pollen season is defined as the first and the last days when the pollen count is greater than or equal to 30 grains/m^3 [Sanchez Mesa, *et al.*, 2003].
Davies and Smith [1973] observed that when the mean daily concentration of grass pollen grains in the air of Central London exceeded 50 grains/m^3 all the patients in the area who were clinically sensitive to grass pollen experienced symptoms of pollinosis.

It was decided to divide the pollen season of Grass and Urticaceae into three periods, pre-peak, peak and post-peak since the behaviour of the pollen seasonal variation curve differs according to these phases. Pre-peak period was established as the period running from the start of pollen season until the day when the start of peak period is recorded. Peak period was defined as the period running from the start of peak period till the 80% of the cumulative values has been reached. The post peak period was defined as the period running from the day when the 80% of the cumulative values has been reached till the day when the end of the pollen season (with the appropriate chosen method). For Olea, it was decided that the pollen season was divided into two periods, pre and post peak. The pre-peak period was defined as the period from the day when three consecutive days with 1p/m^3 was found till the start of peak period. The post-peak period was defined as the period from the end of peak period till the day with 1p/m^3 was recorded.

The division of the main pollen season into three was not possible with the "Threshold 30" method as in most years the end of the grass pollen season with "threshold 30" method coincides nearly on the same day when the 80% of the cumulative values has been reached. This was evident for 1995, 1998 and 2002. Thus, it was not possible to compile a table with the "Threshold 30" method to investigate the length of the grass pollen season and for each period of the pollen season. It was decided then to use the two other methods (2.5% and 5%).

For Grass and Urticaceae the 2.5% method and 5% method were used. Later, for the construction of the daily forecast models, only 5% method was used. By these methods, the season start dates were defined as 2.5% and 5% of the cumulative seasonal total and the end date was defined at the 97.5% and 95% level [Pathirane, 1975; Trigo *et al.*, 1996]. The initial and final 2.5% and 5% of the annual curve were eliminated to avoid lengthy tail-off.

Although various criteria are in use for defining the start date the 2.5% and 5% were chosen due to relatively low airborne pollen concentrations especially for the Urticaceae family.

Grass and Nettle pollen seasons were split into three (pre-peak, peak and post-peak period of pollen dispersal) in order to investigate temporal differences throughout their pollen seasons. It was initially decided to adopt the method proposed by Pathirane [1975] where cumulative percentages of daily pollen are graphically depicted and the main period of pollen dispersal lies between the inflections of the sigmoid curve (fig 9-13 a-d).

This method proved adequate for predicting the beginning of the peak period of pollen dispersal but rather subjective when used to predict the end of this period. For this reason, it was decided to use the method 80% as an arbitrary figure that represents the end of the peak period within the sigmoid curve. It should be noted as Galan *et al.*, [1995] has explained, that this method is effective in sites where the pollen season for grass is more clearly defined such as Cordoba.

Cordoba has the similar climate to Tirana as both are in the Mediterranean climate. In order for the end of the peak period of pollen dispersal to be forecast quantitavely it was decided that this period should end when the 80% of the pollen for that season had been released.

The Tirana pollen seasons for three taxa statistics are depicted in Tables 3-10.

Table 3 a-c shows the grass pollen season with three different methods. With the “Threshold 30” method the grass pollen season starts in the middle of May and ends in the middle of June.

The grass pollen season was defined by two other methods (2.5% and 5% method) it was longer. With 2.5% method the grass pollen season started by the last week of April except the year 2002 where in both methods the grass pollen season started earlier than other years. Also the peak value date and end of the season was earlier in 2002 and this was clearer with the method 2.5%. The end of the grass pollen season differs with two methods. With 2.5% method the end of pollen season occurs by the end of July (mean 20/7) and with the other method (5%) occurs a bit earlier (mean 18/7).

It should be noted that the mean date of the peak value for both methods mentioned occur on the same day (22/5). Also the end of the peak period for both the methods occurs on the same day, day 177 (19/6).

Tables 7 and 9 show the length of grass pollen season in days as well as the sum of grass pollen in each season and length of pre-peak, peak and post peak periods of pollen release.

By comparing those to tables it could be seen that the grass pollen season with 2.5% method was longer (98 days) than with 5% method (80 days). This was also experienced for the length of grass pollen in the peak (mean 33 days) and post peak period (mean 37 days) but not for the length of the peak period, which was longer with 5% method (30 days). Also the tables show the sum of the grass pollen season for each year showing the higher grass pollen concentrations in year 1996 with 2404 grass pollen grains and the lowest one in year 1995 with 1262 grass pollen grains.

Table 4 a-b shows the Urticaceae pollen season defined by two methods (2.5% and 5% method). With the 2.5% method, the Urticaceae pollen season starts earlier (mean value =18/5) than with 5% method (mean value= 25/5). It should be noted that the Urticaceae pollen season start usually after the second week of May. The exception with the earlier start of Urticaceae pollen season with 2.5% method was the start of peak period which was earlier in method 5% occurred on day 159 (mean value) (15/6). The start of peak period with 2.5% method occurred on day 169 (18/6).

Tables 8 and 10 show the length of Urticaceae pollen season in days as well the sum of Urticaceae pollen in each season and the length of pre-peak, peak and post peak periods of pollen release.

On average the length of the Urticaceae pollen season was longer with the 2.5% method (159 days) than with 5% method (145 days). There are great differences in the length of pre-peak period with the longest one with 5% method (84 days) and the shortest one with 2.5% method (32 days). The length of the peak period occurs near the same day (mean 83 days for 2.5% method and 84 days for 5% method). Also the difference in the length of post-peak period is approximately 14 days with the shortest one with the 2.5% method (42 days) and the longest one with 5% method (30 days).

The mean annual sum of Urticaceae pollen is 1210 pollen grains for four years with the higher pollen concentrations registered in year 1995 (1657 pollen grains) and the lowest one in year 1998 (740 pollen grains).

With the "Threshold 1" method the start of Olea pollen season occurs by the second and third week of May, as shown by Table 5 except in the year 2002 when the Olea pollen season started earlier on 18/5. The earlier start of pollen season in 2002 was experienced with grass in both methods but not with Urticaceae. The end of the Olea pollen season was as a mean of four years in day 170 (11/6).

Table 6 includes the Tirana Olea pollen season statistics, including the sum of Olea pollen season and the length of peak, pre-peak and post peak period. The length of Olea pollen season was short with a average of 32 days in the four years study. Also the length of the pre-peak was short with the longest one in year 2002 (10 days) and the shorter one in year 1998 (4 days). By comparing the three periods of the main pollen season the length of post peak period in Olea pollen season was longer (16 days mean). The sum of Olea as an average of four years was 1332 pollen grains. The year 1995 has the higher total sum of Olea pollen concentrations with 2088 pollen grains and the year 1998 has the lowest pollen concentrations with only 717 pollen grains in the air.

The Olea pollen season was divided into two periods, pre and post peak period. The pre-peak period was considered the period from the start of pollen season with 1% till the maximum pollen counts and the post peak from the maximum pollen count till the end of pollen season with 1% method.

Table 3 (a-c). Start and end dates of Tirana grass pollen season (1995,1996,1998,2002) with different methods including start and end of the peak period of pollen dispersal

a)

Year	Start of grass pollen season (Threshold 30)		Start of peak period in grass pollen season Pathirane (1975)		End of peak period in grass pollen season 80% method		End of Grass pollen season Threshold 30 method	
	Date	Day	Date	Day	Date	Day	Date	Day
1995	16/5	136	17/5	137	7/6	158	12/6	163
1996	18/5	139	18/5	139	10/6	162	17/6	169
1998	14/5	134	14/5	135	31/5	151	16/6	167
2002	16/5	136	14/5	135	26/6	177	26/6	177
Mean	16/5	136	15/5	144	19/6	162	18/6	169

b)

Year	Start of grass pollen season (Method 2.5%)		Start of peak period in grass pollen season Pathirane (1975)		End of peak period in grass pollen season 80% method		End of Grass pollen season (Method 97.5%)	
	Date	Day	Date	Day	Date	Day	Date	Day
1995	21/4	111	18/5	138	20/6	171	27/7	208
1996	28/4	119	19/5	140	14/6	166	2/8	215
1998	25/4	115	21/5	142	16/6	167	28/7	209
2002	10/4	100	14/5	135	26/6	177	24/7	205
Mean	21/4	111	18/5	138	19/6	177	20/7	209

c)

Year	Start of grass pollen season (Method 5%)		Start of peak period in grass pollen season Pathirane (1975)		End of peak period in grass pollen season 80% method		End of Grass pollen season (Method 95%)	
	Date	Day	Date	Day	Date	Day	Date	Day
1995	2/5	122	17/5	137	19/6	170	20/7	201
1996	8/5	129	18/5	139	13/6	165	14/7	196
1998	1/5	121	14/5	135	16/6	167	24/7	205
2002	22/4	112	14/5	135	26/6	177	15/7	196
Mean	8/5	121	15/5	144	19/6	170	18/7	200

Table 4 (a-b). Start and end dates of Tirana Urticaceae pollen season 1996, 1996, 1998, 2002 with different methods including start and end of the peak period of pollen dispersal

a)

Year	Start of Urticaceae pollen season (Method 2.5%)		Start of peak period in Urticaceae pollen season Pathirane (1975)		End of peak period in Urticaceae pollen season 80% method		End of Urticaceae pollen season (Method 97.5%)	
	Date	Day	Date	Day	Date	Day	Date	Day
1995	13/5	133	8/6	160	23/8	235	17/10	290
1996	22/5	143	18/6	169	30/8	243	9/10	283
1998	14/5	134	5/6	146	19/9	262	1/11	305
2002	21/5	141	8/6	159	26/9	269	3/11	307
Mean	18/5	138	7/6	158	25/8	252	8/10	296

b)

Year	Start of Urticaceae pollen season (Method 5%)		Start of peak period in Urticaceae pollen season Pathirane (1975)		End of peak period in Urticaceae pollen season 80% method		End of Urticaceae pollen season (Method 95%)	
	Date	Day	Date	Day	Date	Day	Date	Day
1995	28/5	148	3/5	151	26/8	238	28/9	271
1996	23/5	144	6/6	158	29/8	242	30/9	274
1998	21/5	141	25/5	145	19/9	257	23/10	297
2002	26/5	146	6/3	154	29/9	269	28/10	301
Mean	25/5	145	1/6	152	26/9	253	27/10	286

Table 5. Start and end dates of Tirana Olea pollen seasons 1995,1996, 1998, 2002 including start and end of the peak period of pollen dispersal

Year	Start of Olea pollen season (Threshold 1 method)		Start of peak period in Olea pollen season Pathirane (1975)		End of peak period in Olea pollen season 80% method		End of Olea pollen season (Threshold 1 method)	
	Date	Day	Date	Day	Date	Day	Date	Day
1995	24/5	144	29/5	149	10/6	161	4/7	185
1996	24/5	145	27/5	148	8/6	159	24/6	176
1998	14/5	135	20/5	141	28/5	148	8/6	159
2002	9/5	129	17/5	138	24/5	144	7/6	158
Mean	18/5	138	24/5	144	18/5	153	11/6	170

Table 6. Tirana Olea pollen season statistics: including sum of Olea pollen season, length of season and length of pre-peak, peak and post peak periods (Method 1)

Year	Length of Olea pollen season (Days)	Length of Olea in pre-peak period (Days)	Length of Olea in peak period (Days)	Length of Olea in post-peak period (Days)	Sum of Olea in pollen season
1995	41	9	6	24	2088
1996	31	4	7	18	1059
1998	25	9	4	10	717
2002	29	10	4	13	1464
Mean	32	8	5	16	1332

Table7. Tirana Grass pollen season statistics: including sum of grass pollen in season, length of season and length of pre-peak, peak and post peak periods (Method 2.5%)

Year	Length of Grass pollen season (Days)	Length of Grass in pre-peak period (Days)	Length of Grass in peak period (Days)	Length of Grass in post-peak period (Days)	Sum of Grass in pollen season
1995	98	39	23	34	1262
1996	93	28	19	44	2404
1998	94	27	24	41	1574
2002	165	38	38	27	1520
Mean	98	33	26	37	1690

Table 8. Tirana Urticaceae pollen season statistics: including sum of grass pollen in season, length of season and length of pre-peak, peak and post peak periods (Method 2.5%)

Year	Length of Urticaceae pollen season (Days)	Length of Urticaceae in pre-peak period (Days)	Length of Urticaceae in peak period (Days)	Length of Urticaceae in post-peak period (Days)	Sum of Urticaceae in pollen season
1995	157	70	32	53	1657
1996	140	11	92	35	1637
1998	171	13	114	42	740
2002	166	33	94	37	804
Mean	159	32	83	42	1210

Table 9. Tirana Grass pollen season statistics: including sum of grass pollen in season, length of season and length of pre-peak, peak and post peak periods (Method 5 %)

Year	Length of Grass pollen season (Days)	Length of Grass in pre-peak period (Days)	Length of Grass in peak period (Days)	Length of Grass in post-peak period (Days)	Sum of Grass in pollen season
1995	84	26	38	18	1262
1996	67	18	19	28	2492
1998	84	21	24	37	1524
2002	84	26	38	18	1520
Mean	80	23	30	25	1690

Table 10. Tirana Urticaceae pollen season statistics: including sum of grass pollen in season, length of season and length of pre-peak, peak and post peak periods (Method 5 %)

Year	Length of Urticaceae pollen season (Days)	Length of Urticaceae in pre-peak period (Days)	Length of Urticaceae in peak period (Days)	Length of Urticaceae in post-peak period (Days)	Sum of Urticaceae in pollen season
1995	138	70	36	30	1657
1996	130	92	92	26	1637
1998	155	114	114	33	740
2002	155	94	94	31	804
Mean	145	84	84	30	1210

Fig. 9 a

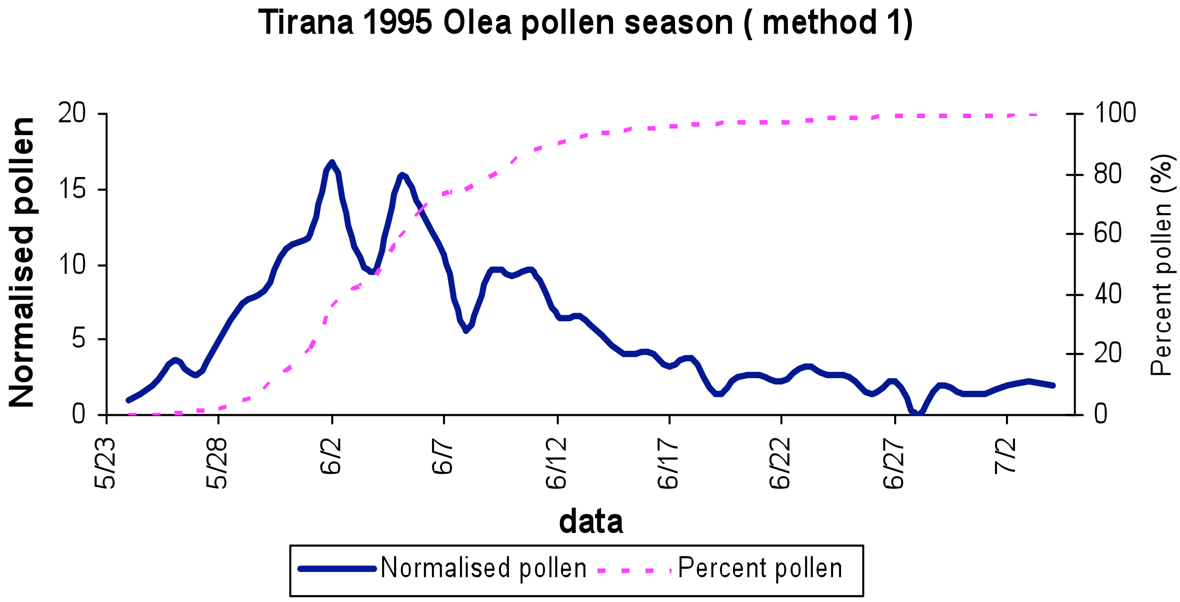

Tirana 1995 Olea pollen season (method 1)
Normalised pollen
20
15
10
5
0
5/23
5/28
6/2
6/7
6/12
6/17
6/22
6/27
7/2
data
100
80
60
40
20
0
Percent pollen (%)
Normalised pollen
Percent pollen

Fig. 9 b

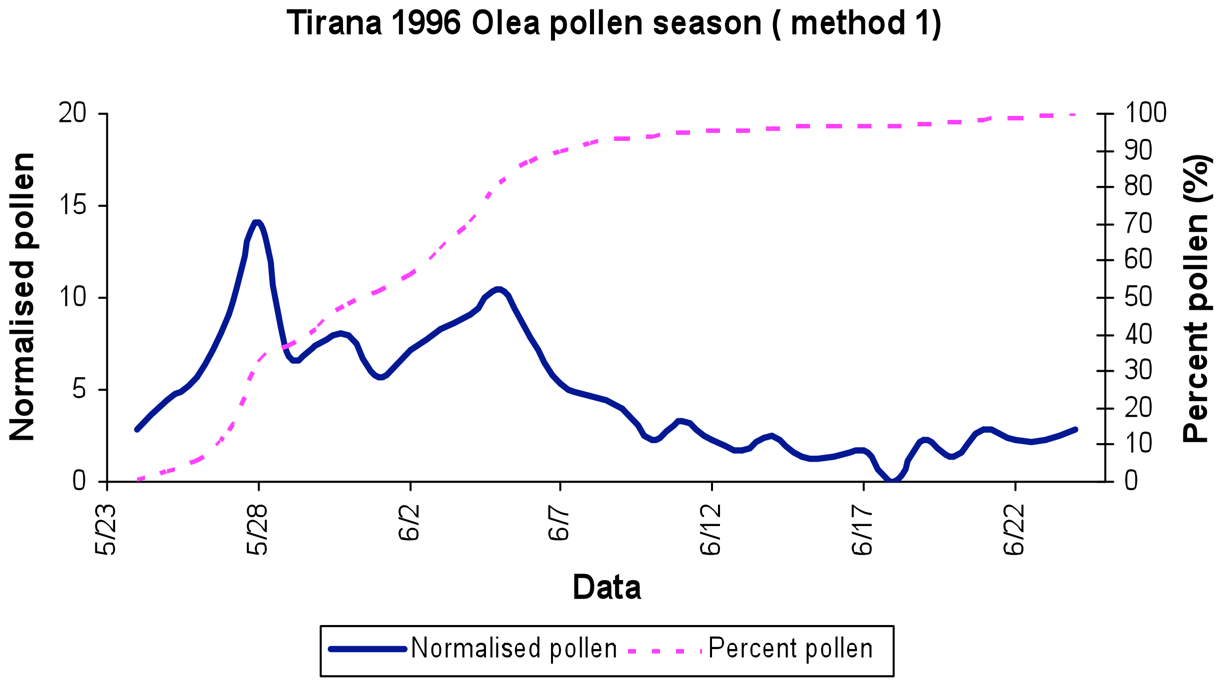

Tirana 1996 Olea pollen season (method 1)
Normalised pollen
20
15
10
5
0
5/23
5/28
6/2
6/7
6/12
6/17
6/22
Data
100
90
80
70
60
50
40
30
20
10
0
Percent pollen (%)
Normalised pollen
Percent pollen

Fig. 9 c

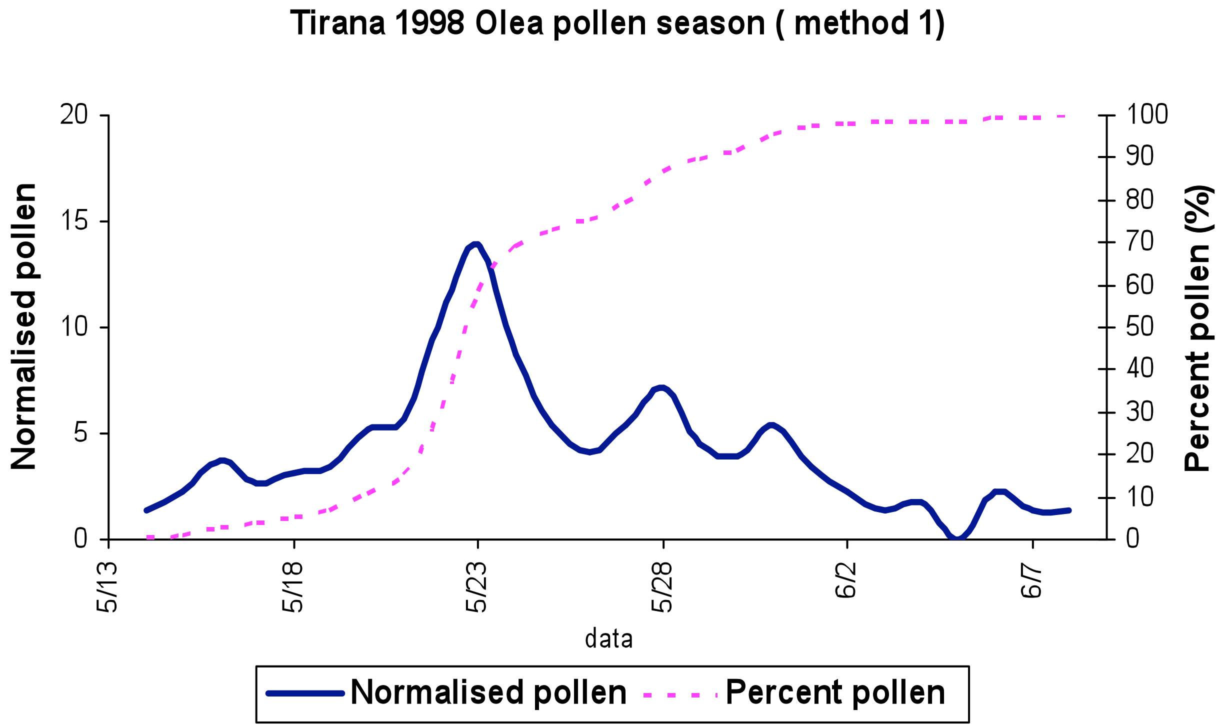


Fig. 9d

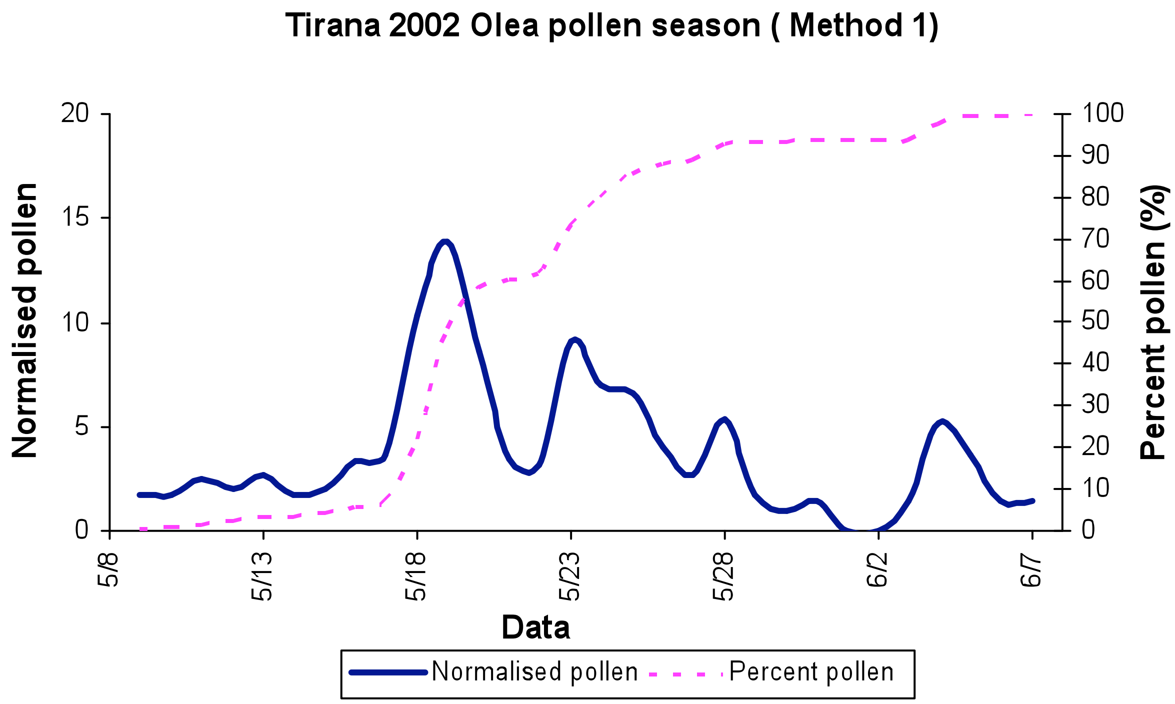


Fig 10 a

Fig 10 a Tirana 1995 Grass pollen season(method 2.5%)

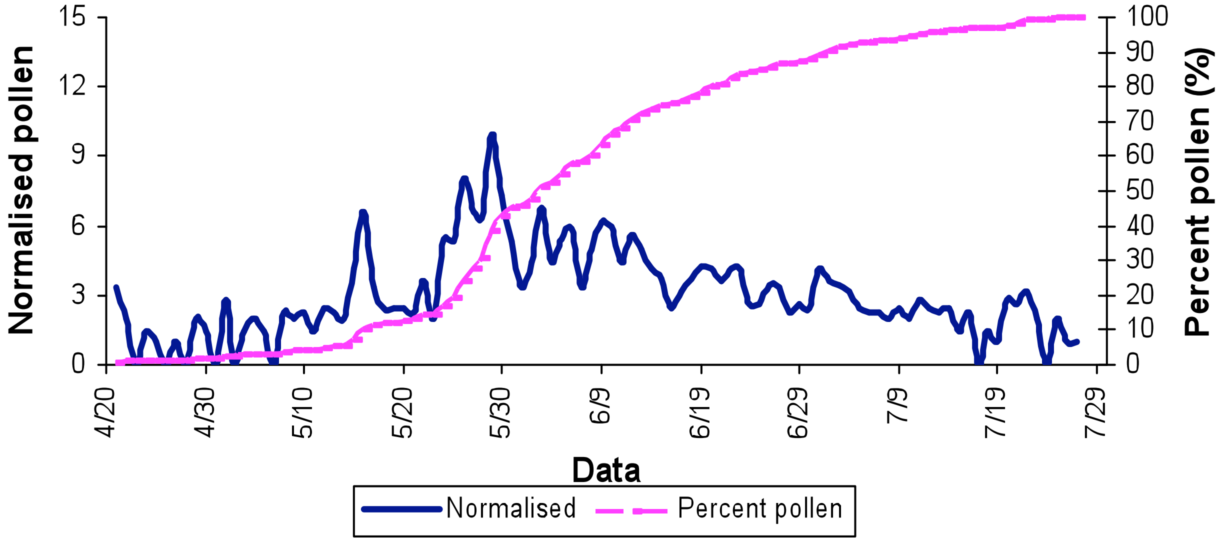


Fig 10 b
Tirana 1996 Grass pollen season (method 2.5%)

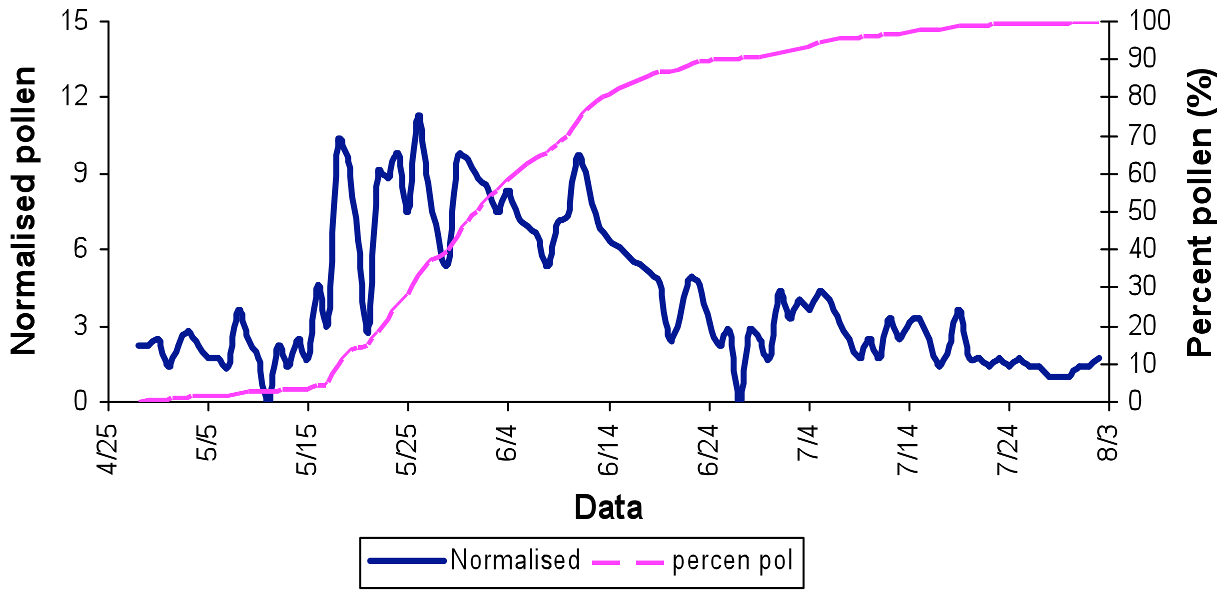
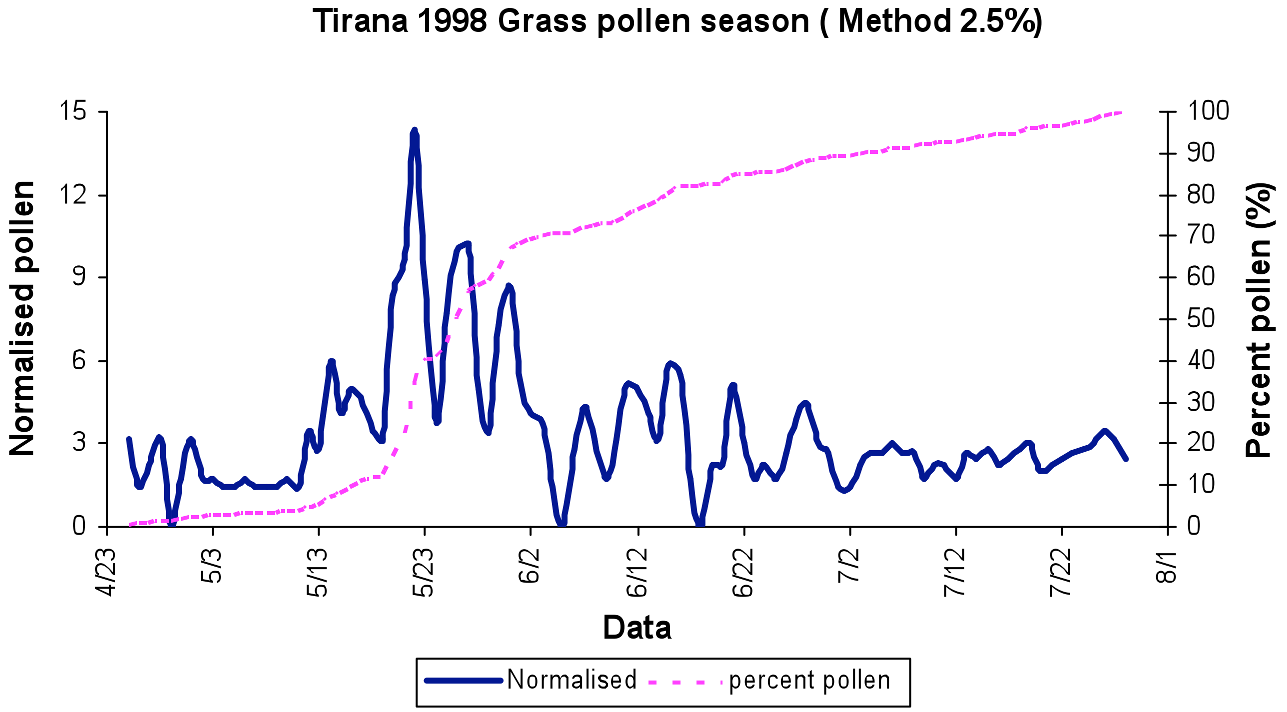


Fig. 10 c,d


Tirana 1998 Grass pollen season (Method 2.5%)
Normalised pollen
Percent pollen (%)
Data
Normalised
percent pollen

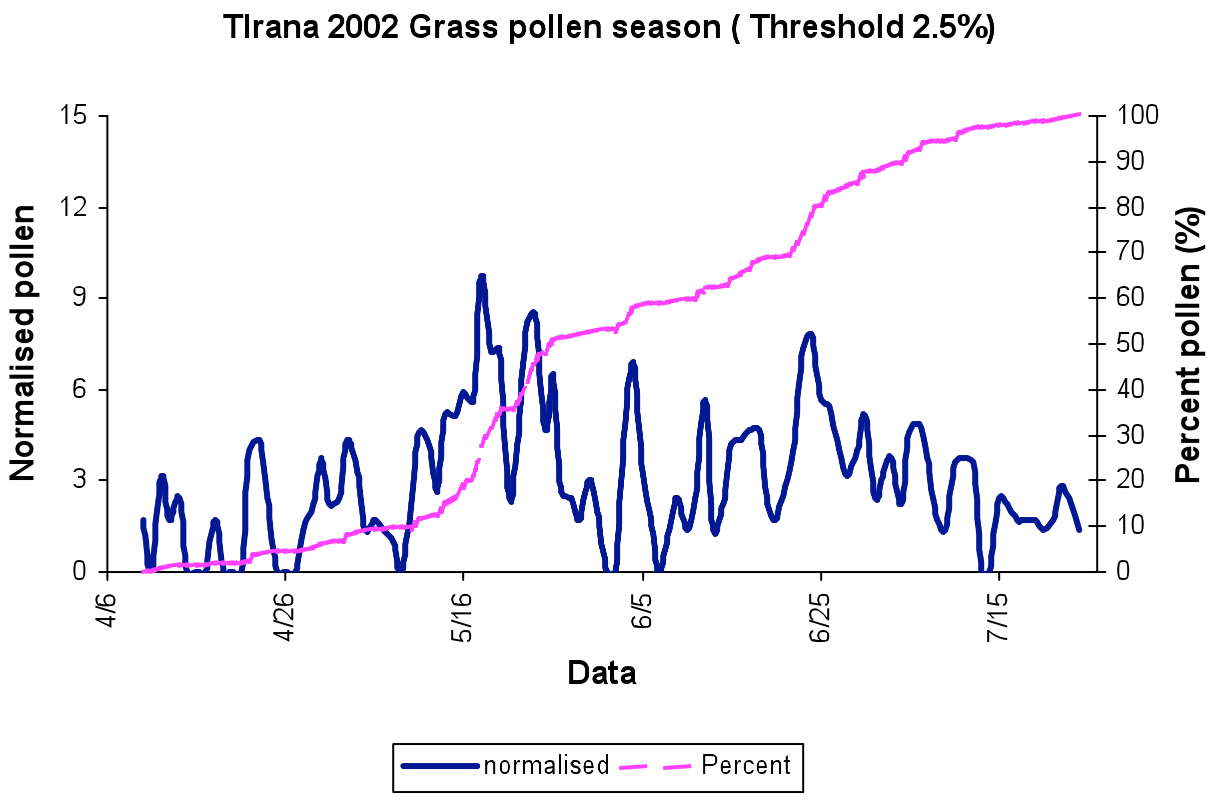

TIrana 2002 Grass pollen season (Threshold 2.5%)
Normalised pollen
Percent pollen (%)
Data
normalised
Percent

Fig. 11 a

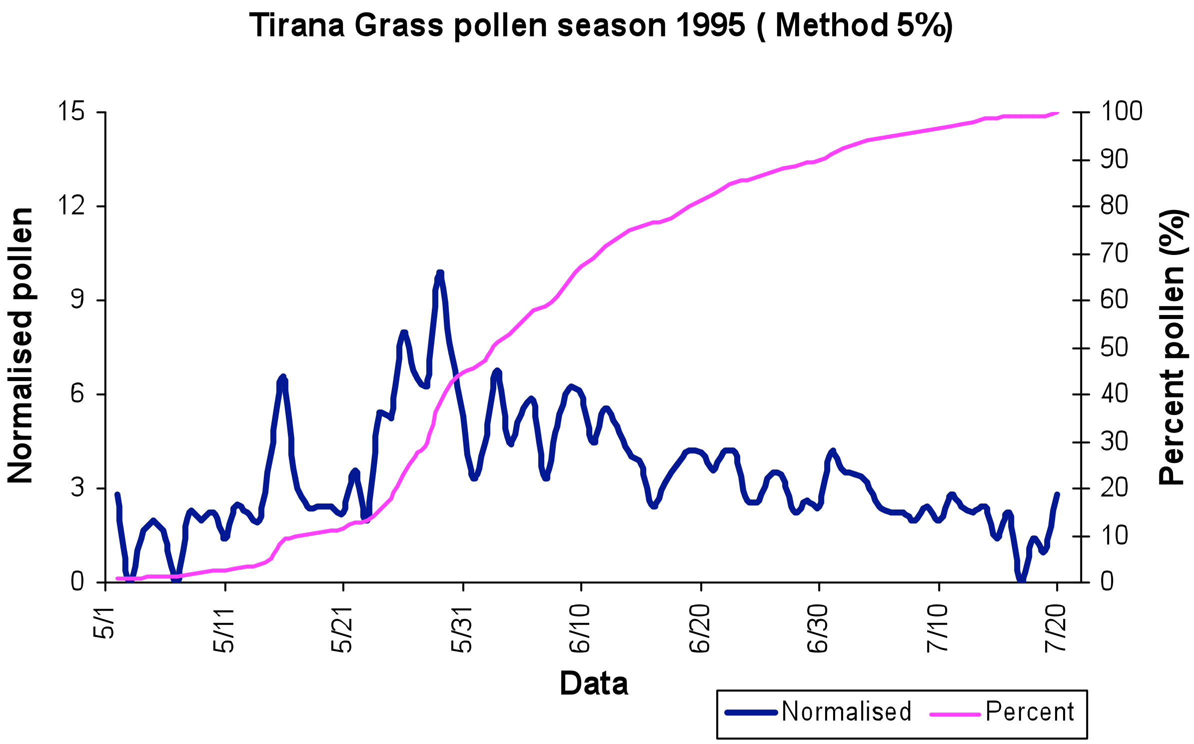


Fig.11 b

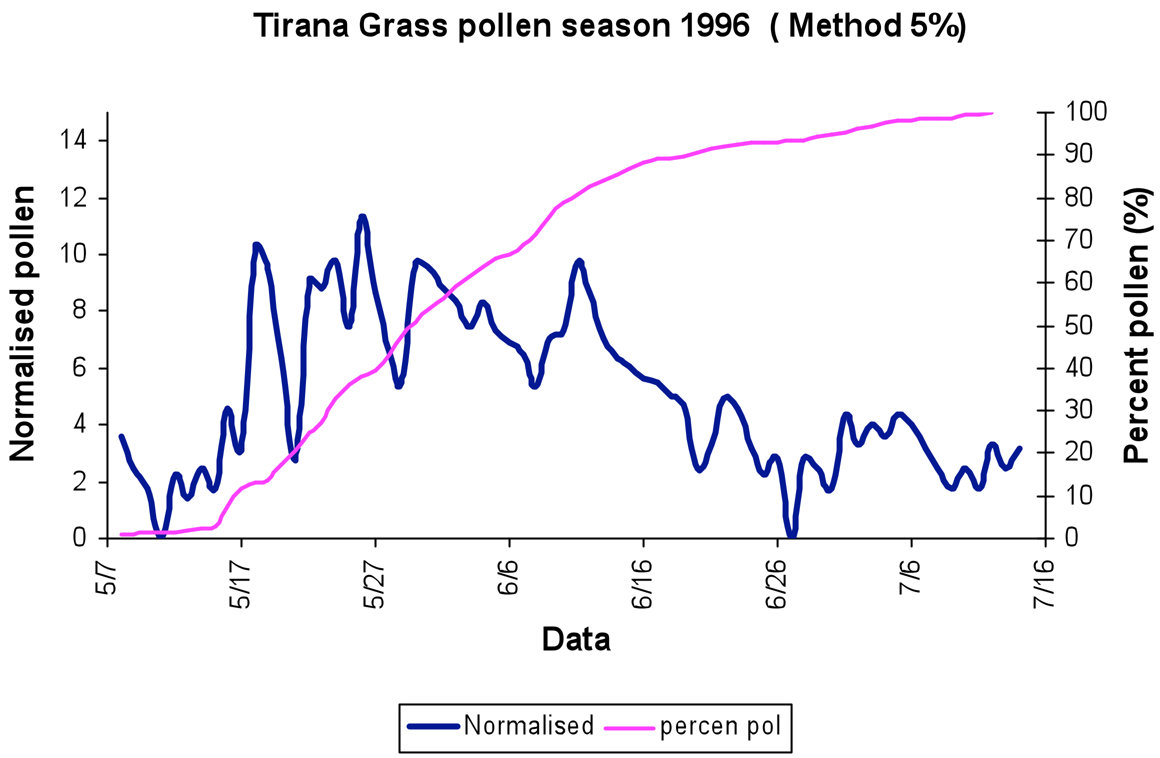


Fig. 11 c

Tirana Grass pollen season 1998 (Method 5%)

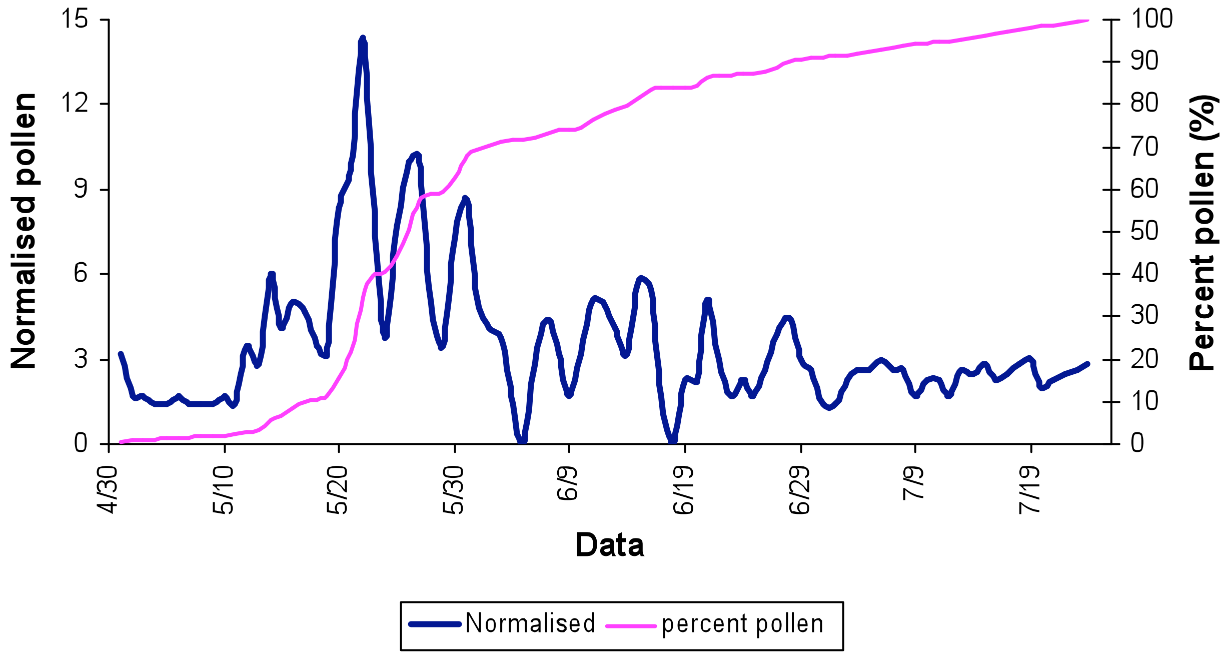


Fig. 11 d

Tirana grass pollen season 2002 (Method 5%)

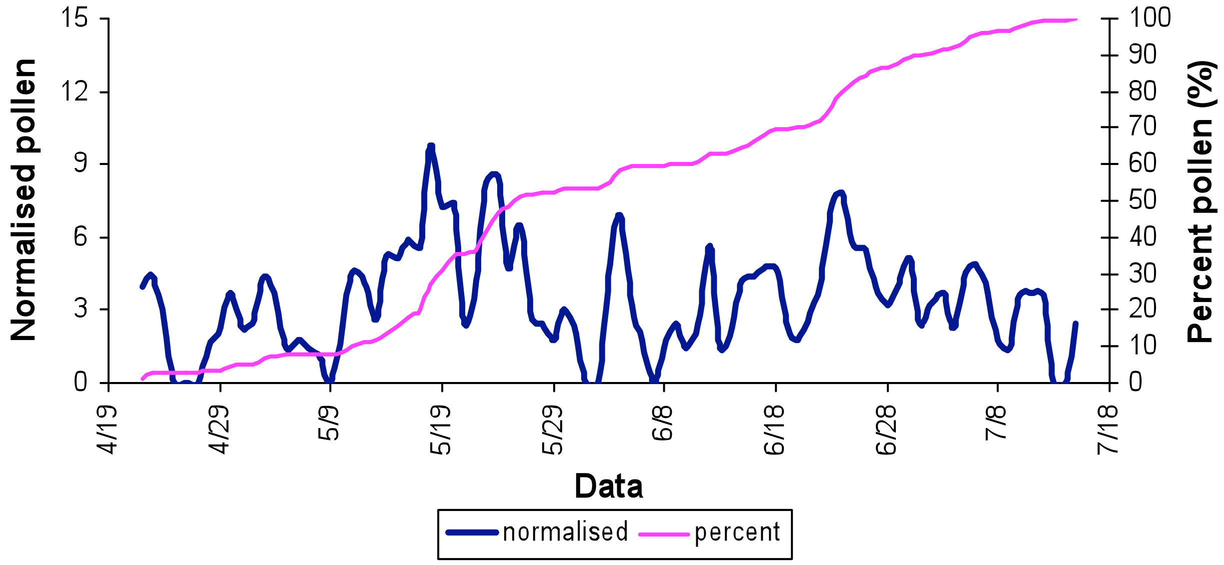


Fig. 12 a

Tirana 1995 Urticaceae (Method 2.5%)

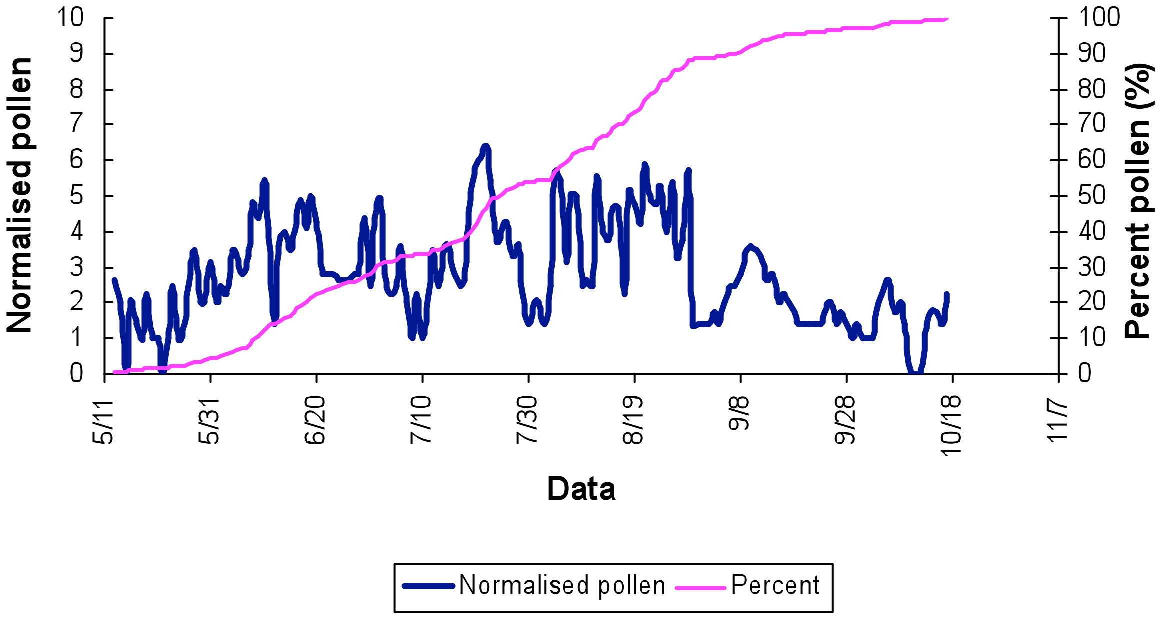


Fig. 12 b

Tirana Urticaceae 1996 pollen season (Method 2.5%)

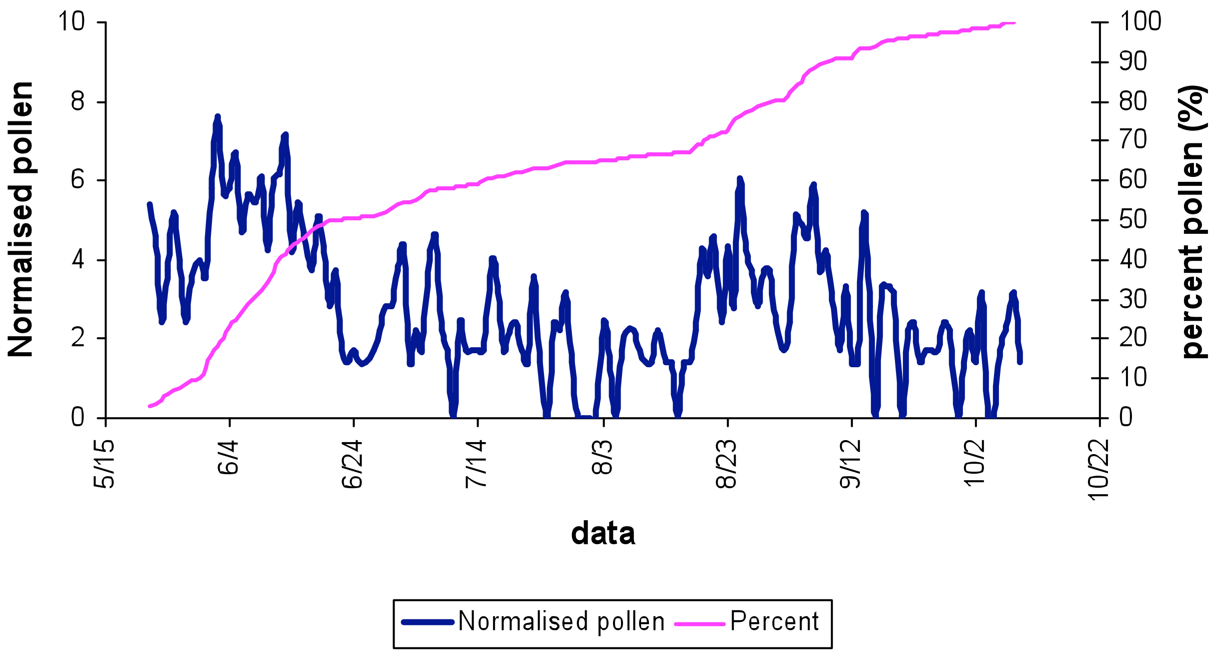


Fig.12 c

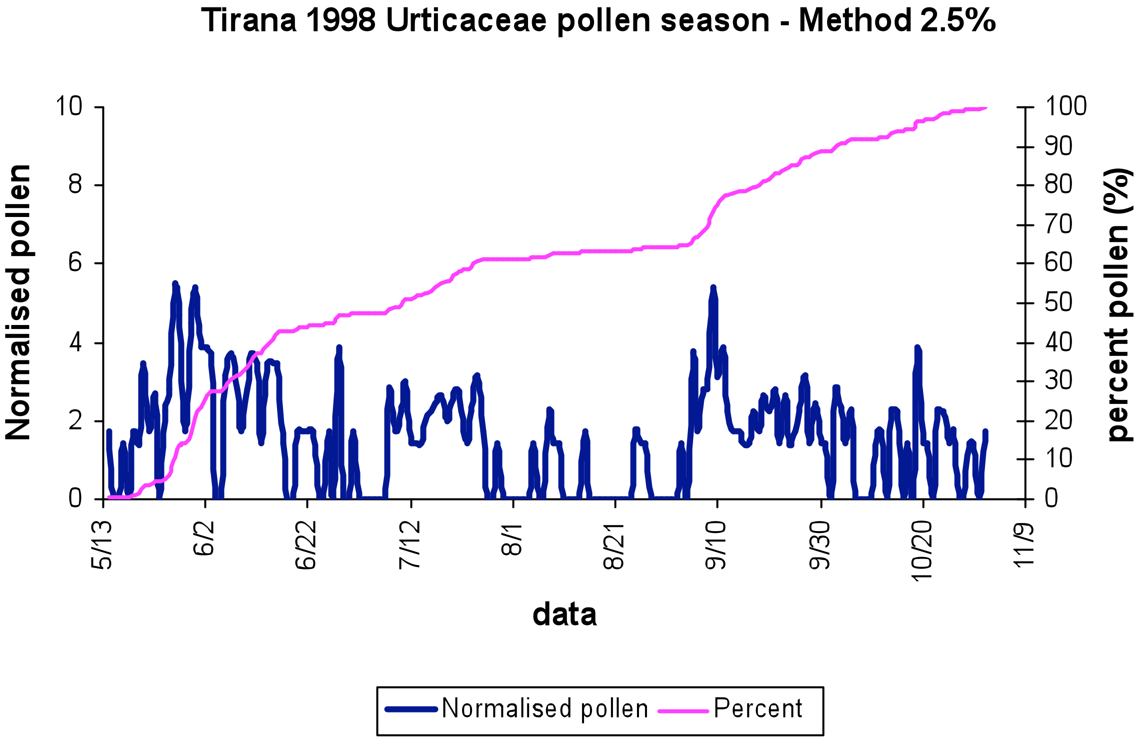


Fig. 12 d

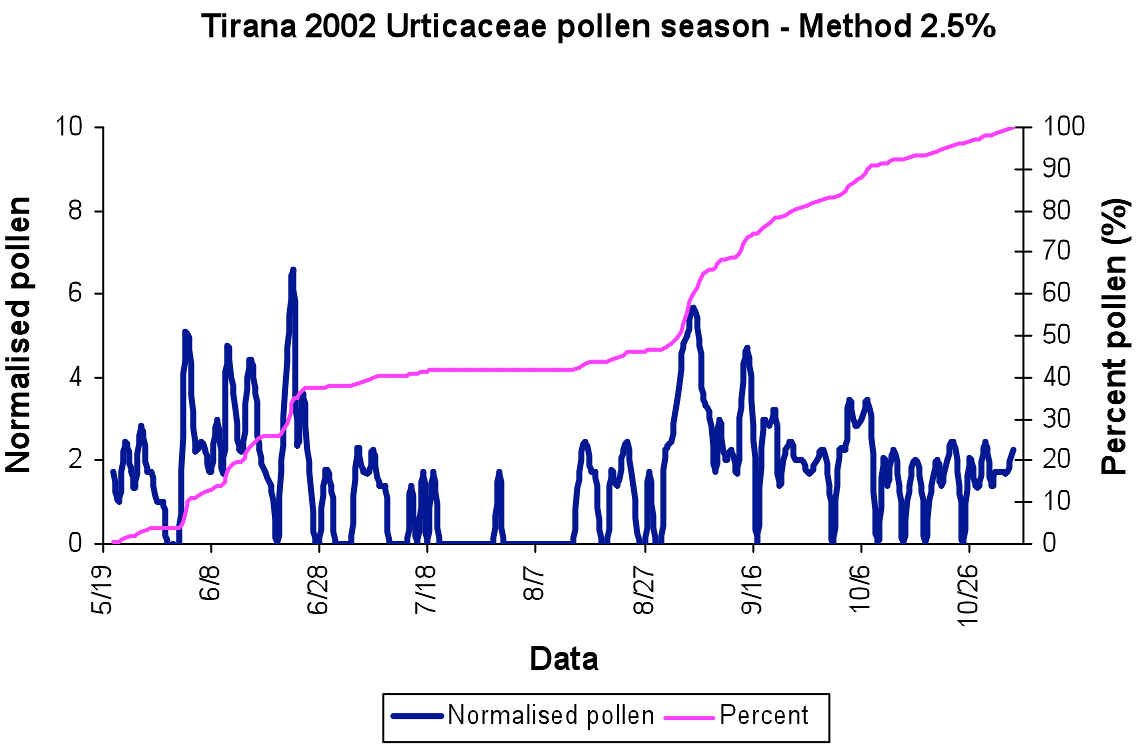


Fig. 13 a

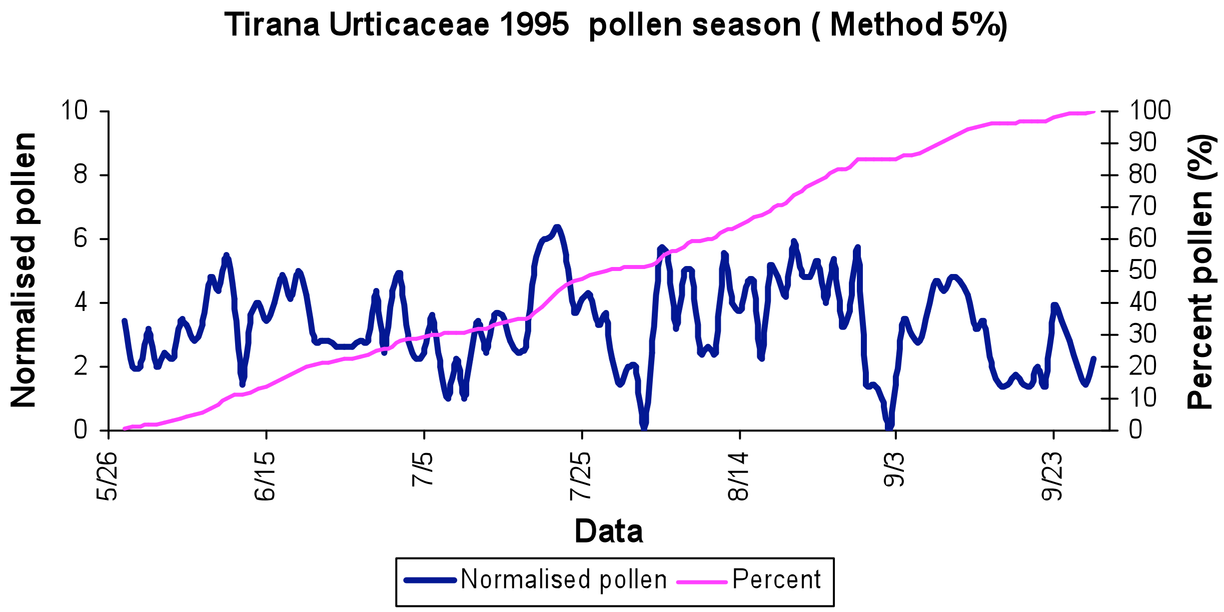


Fig. 13 b

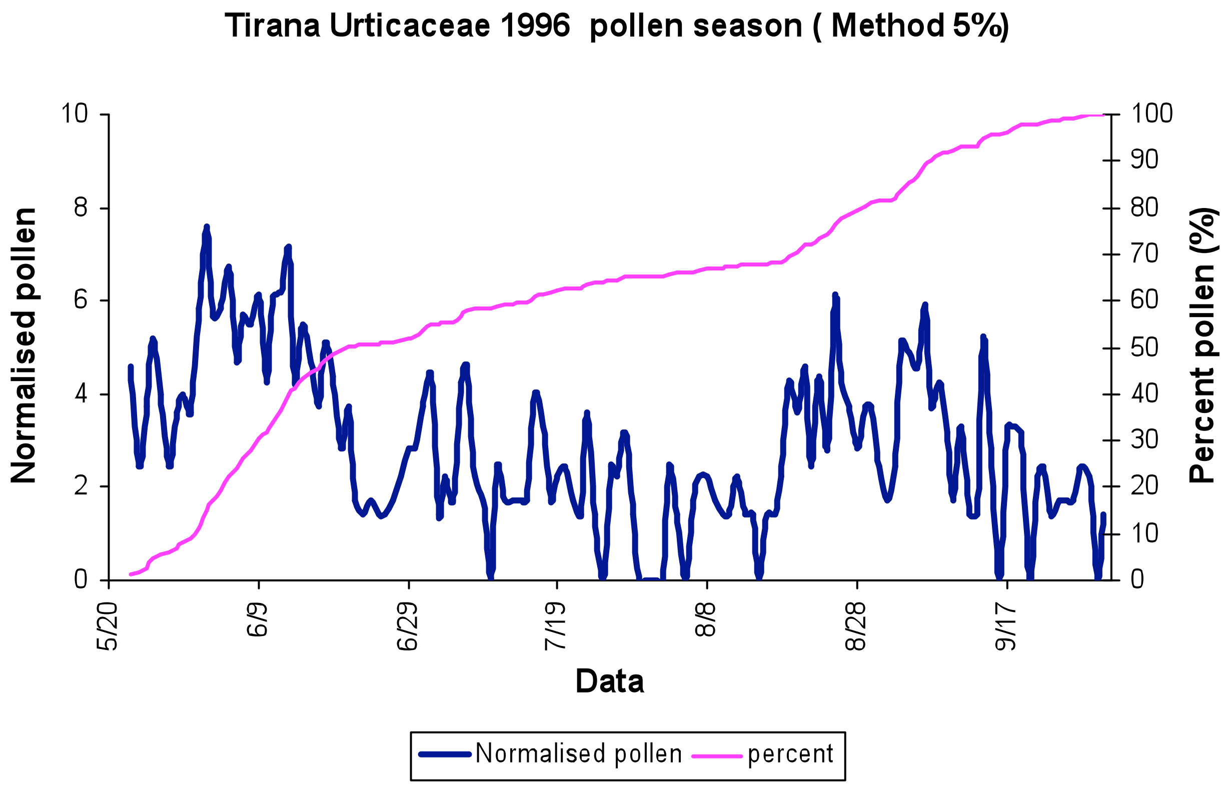


Fig.13 c

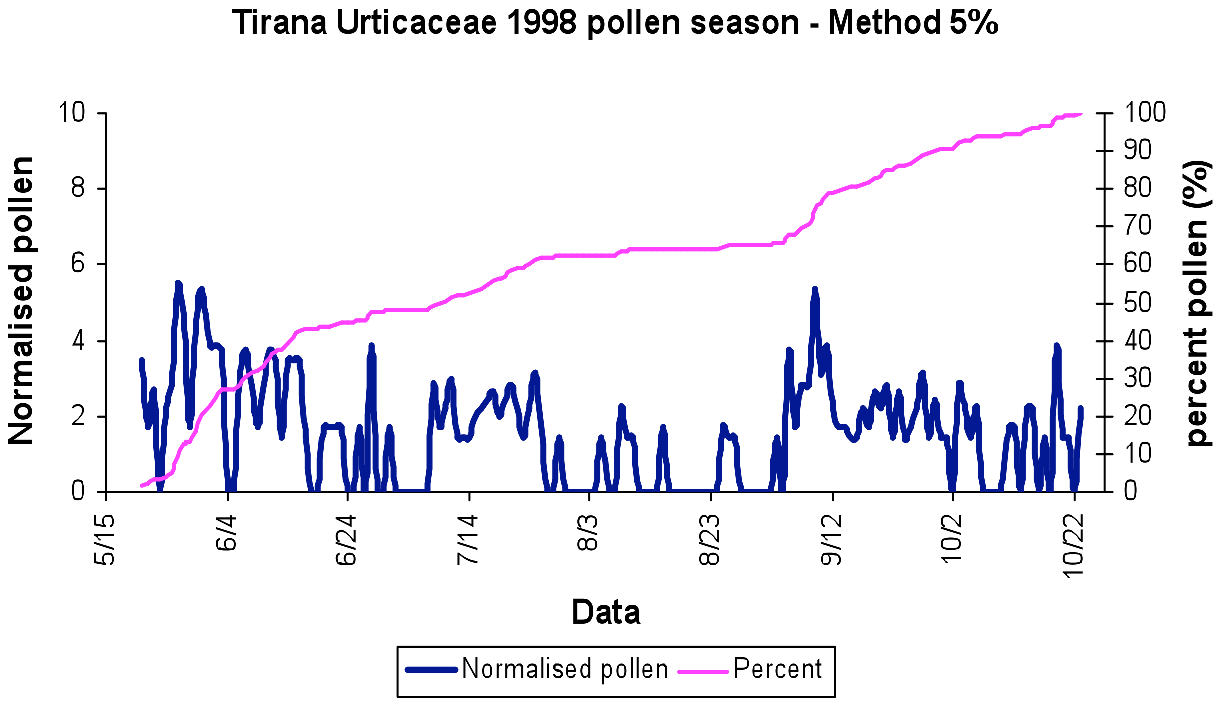
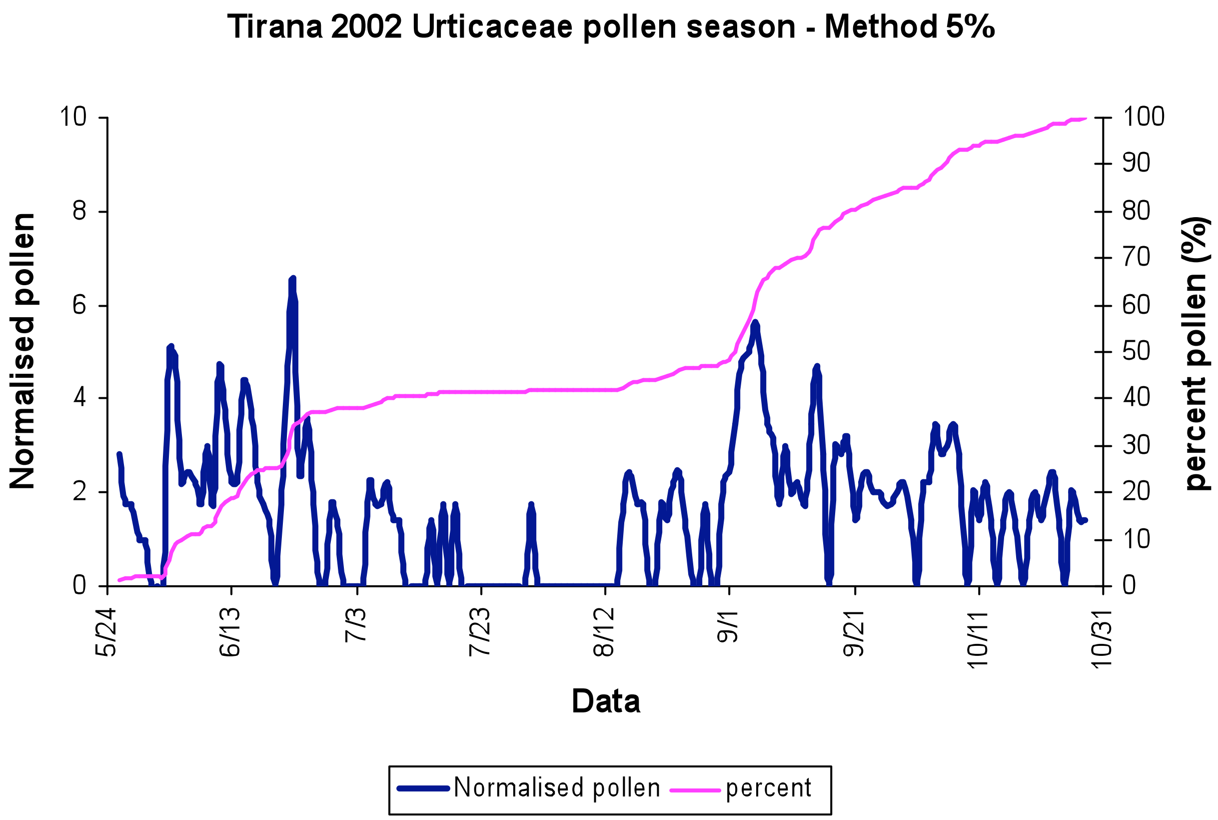


Fig. 13 d



CHAPTER FIVE
ANALYSIS OF POLLEN COUNTS IN RELATION TO METEOROLOGICAL VARIABLES

The results summarised in Tables 11-33, are those obtained by Pearson correlation and show the significant relationships between certain characteristics of the Poaceae, Olea, Urticaceae pollen seasons and maximum temperature, minimum temperature and rainfall in Tirana during the four years of study *[full results of correlation analysis are shown in Appendices B-D]*. A detailed methodology for this work has been given in Chapter 4. For these analyses, the start and end of the Poaceae and Urticaceae pollen seasons were calculated using the 5% method, the start and end of the Olea pollen season was calculated using method 1. These analyses could be taken as an illustrative of the direction and strength of the relationships. Note that because of the small sample size (4 years) the results of correlation analyses presented in this section should be regarded with some caution. However, the results are still useful because they give an indication of the environmental factors that influence the start, end, severity and length of the pollen seasons examined.

5.1. Results and discussion

5.1.1 The Grass pollen season

Table 11 shows the significant results of correlations between the maximum temperature and minimum temperature between the days 41-90 (two months before the pollen season) and the start of grass pollen season. All the correlations are negative. This means that if the temperature is higher, the pollen season starts earlier and the opposite if the temperature gets lower, the pollen season tends to start later. The highest correlation coefficient found and later used for the linear regression to predict the start of grass pollen season, was the variable maximum temperature from days 61-70, from 1st of January. The coefficient correlation for this variable was -.0.99** (correlation is significant at the 0.01 level).

Also it was observed from the correlations that the minimum temperature at the period from days 1-40 has a positive correlation with the start of the pollen season. In this case when the minimum temperature gets higher the start dates gets later. The opposite occurs if the minimum temperature gets lower. The number of significant correlations between the temperature variables (maximum temperature and minimum temperature) from day 40 to day 90 from January 1st and start dates for Grass indicates that the temperature at this time is important for the start of the pollen season.

Table 11 Significant correlations between certain characteristics of grass pollen season (Method 5%) and meteorological variables in Tirana during the four years of study

		Correlation coefficient	
Start	Minimum temperature from days 1-40 from Jan 1st	0.977	*
	Minimum temperature mean from days 41-70 from Jan 1st	*-0.961*	*
	Minimum temperature from days 51-70 from Jan 1st	*-0.972*	*
	Maximum temperature from days 61-70 from Jan 1st	***-0.999***	**
	Maximum temperature mean from days 31-50 from Jan 1st	*-0.965*	*
	Maximum temperature from days 41-80 from Jan 1st	*-0.951*	*
	Maximum temperature mean from days 51-90 from Jan 1st	*-0.993*	*
	Maximum temperature from days 61-90 from Jan 1st	*-0.964*	*
	Maximum temperature from days 61-80 from Jan 1st	*-0.988*	*
End	Rain mean days from days 10-40 from Jan 1st	0.958	*
	Rain days 11-20 from 1st of Jan	**0.991**	*
	Rain days 31-40 from 1st of Jan	0.955	*
	Rain days from 91-120 from Jan 1st	0.976	*
	Minimum temperature days from 41-50 from Jan 1st	*-0.965*	*
	Maximum temperature days 131-150 from Jan 1st	*-0.958*	*
Severity	**Rain days from 121-160 from Jan 1st**	***-0.990***	*
Length	Minimum temperature days from 51-70 from Jan 1st	0.966	*
	Minimum temperature days from 61-70 from Jan 1st	0.970	*
	Minimum temperature days from 101-120 from Jan 1st	0.953	*
	Maximum temperature mean from days 31-50 from Jan 1st	0.996	*
	Maximum temperature days from 41-50 from Jan 1st	**0.996**	**
	Maximum temperature days from 51-150 from Jan 1st	0.952	*
	Maximum temperature days from 41-80 from Jan 1st	0.988	*
	Maximum temperature mean from days 41-70 from Jan 1st	0.957	*
	Maximum temperature mean from days 51-70 from Jan 1st	0.967	*
	Maximum temperature days 61-70 from Jan 1st	0.969	*
	Maximum temperature days 141-160 from Jan 1st	*-0.990*	**

*** Correlation is significant at the 0.05 level (2-tailed).**
**** Correlation is significant at the 0.01 level (2-tailed).**
Normal text indicates positive relationships

It is generally accepted that temperature influences many aspects of the growth of plants and this influence is also of great importance in determining the time of flowering. Also previous work has shown [Frenguelli *et al.*, 1991; Emberlin *et al.*, 1994] that higher temperatures accelerate the process of ripening of the flowers and consequently, the starting dates of the pollen season will be earlier.

A number of positive correlations were found between the length of the pollen season and meteorological variables. The temperature (maximum and minimum) seems to play the major factor in determining the length of the grass pollen season specially the temperatures between days 30-70 (February-April). It means that the higher the temperatures (min, max) the longer the pollen season will be. The highest correlation coefficient which was used to predict the length of grass pollen season was the variable temperature maximum on days 41-50 with a correlation of 0.99** (correlation is significant at the 0.01 level - two-tailed).

It seems that in the case of the end of the pollen season most important meteorological variable is rainfall. The correlation coefficient that was correlated better with the end date of the grass pollen season was the variable rain days 11-20 with an correlation coefficient of 0.99* (correlation is significant at the 0.05 level-2 tailed). Also from the observed correlations it seems that rain days from days 10-40 from January 1st and rain days from 91-120 are important in influencing the end dates of the grass pollen season. The positive correlation between the rainfall and end dates indicates that the more abundant rainfall in the winter (10-40 days) leads to a later end of the pollen season and the opposite, the less rainfall in the winter the earlier the grass pollen will be finished. Also the temperatures variables (minimum and maximum) have a negative correlation with the end dates of the grass pollen season.

The Pearson correlations for Grass between the severity and meteorological variables have shown that only one variable had a significance. The Rain days from 121-160 (the middle of the grass pollen season) from January 1st have a negative significant correlation with the severity of the grass pollen season. In this case the more rain during the days period from 121-160 the less total pollen will be recorded in the trap.

5.1.2 The Olea pollen season

Pearson correlation coefficients were calculated for the relationship between the start of Olea pollen season and the meteorological variables. It showed that the variable temperature maximum on days 51-70 has the highest coefficient correlation (0.99*) with the start of Olea pollen season. This variable was entered into the linear regression to predict the start of Olea pollen season. It also showed that the maximum cumulative temperatures in the months preceding the Olea pollination could play an important role for the start of Olea pollen season. The negative significant correlation between the maximum cumulative temperatures and the start dates of Olea show that if the cumulative max temperatures will be higher in the months prior the Olea flowering period the start of Olea pollen season will be earlier. Also the mean maximum temperature from days 10-50 from January 1st showed a negative significance correlation with the start of Olea pollen season. This indicates a relationship with the mean maximum temperature during the development of the buds produced during the preceding year.

From the physiological point of view it is reasonable to suppose that the timing of the flowering period is related to high temperature levels.

The decisive role of the temperature for the start of Olea pollen season has been described by many authors [Galan, *et al.*, 2001, a,; Fornaciari *et al.*, 1998; Alba & Guardia, 1998].

The start of Olea pollen season has a positive significant correlation with the rainfall and that means when the rainfall is abundant in the months prior the Olea pollination period the Olea pollen season will be later. It is well documented for plants, whereby they respond to low levels of rainfall by anticipating anthesis.

The best variable that reached the highest correlation coefficient (-0.99**) with the end date of Olea pollen season was the maximum temperature on days 91-120.This variable was entered into the linear regression to predict the end date of Olea pollen season.

The rainfall from days 41-100 from January 1st has also shown a positive significant correlation with the end dates of the Olea pollen season. This could be interpreted that the more rain during the days (41-100), the later the Olea pollen season will be. Also the same results were achieved with the cumulative rain from the same mentioned period.

Also a number of negative correlations were found between the maximum temperature from days 81-150 from January 1st and the end of the Olea pollen season. It should be noted that the same relationship with temperature and rainfall was found also for the start of the Olea pollen season.

Table 12 Significant correlations between certain characteristics of Olea pollen season (Method 1) and meteorological variables in Tirana during the four years study

		Correlation coefficient	
Start	Rain days from 41-80 from Jan 1st	0.951	*
	Rain mean days from 51-70 from Jan 1st	0.980	*
	Rain mean days from 51-90 from Jan 1st	0.978	*
	Rain days from 51-100 from Jan 1st	0.969	*
	Rain days from 61-80 from Jan 1st	0.971	*
	Rain days from 61-90 from Jan 1st	0.973	*
	Rain days from 81-90 from Jan 1st	0.964	*
	Maximum temperature mean from days 51-70	***0.997***	*
	Maximum temperature mean from days 10-50 from Jan 1st	*-0.992*	*
	Maximum cumulative temperature days 51-100 days from Jan 1st	*-0.960*	*
	Maximum cumulative temperature days 81-100 from Jan 1st	*-0.960*	*
	Maximum temperature from days 91-110 from Jan 1st	*-0.985*	*
End	Rain mean days from 41-70 from Jan 1st	0.989	*
	Rain mean days from 51-70 from Jan 1st	0.973	*
	Cumulative Rain days from 51-100 from Jan 1st	0.963	*
	Rain days from 61-80 from Jan 1st	0.965	*
	Rain days 61-90 from Jan 1st	0.985	*
	Cumulative Rain days from 61-90 from Jan 1st	0.954	*
	Cumulative Rain days from 81-90 from Jan 1st	0.954	*
	Cumulative Rain days from 81-100 from Jan 1st	0.963	*
	Rain days 81-90 from Jan 1st	0.957	*
	Cumulative Rain days from 91-100 from Jan 1st	0.963	*
	Rain days 131-140 from Jan 1st	0.989	*

	Maximum temperature mean from days 10-30 from Jan 1st	-0.987	*
	Maximum temperature days from 81-120 from Jan 1st	-0.951	*
	Maximum temperature days from 91-120 from Jan 1st	**-0.998**	**
	Minimum temperature days from 91-130 from Jan 1st	-0.987	*
Severity	Cumulative maximum temperature from 31-40 from Jan 1st	-0.952	*
	Minimum temperature days from 131-150 from Jan 1st	0.990	**
	Temperature minimum mean days 51-90	**0.990**	**
Length	Maximum temperature days from 10-30 from Jan 1st	-0.953	*
	Rain days from 21-30 from Jan 1st	0.953	*
	Minimum temperature days from 51-90 from Jan 1st	0.977	*

*** Correlation is significant at the 0.05 level (2-tailed).**
**** Correlation is significant at the 0.01 level (2-tailed).**

The minimum temperatures from days 51-90 from January 1st have a positive significant correlation with the severity of the Olea pollen season (0.99*). This could be interpreted as a pattern whereby the higher the minimum temperatures from days 51-90, the more total Olea pollen will be produced.

The correlations between the meteorological variables and the length of Olea pollen season were performed. It has shown that the minimum temperature, maximum temperature and rain in the first three months prior to the Olea pollination period play a important role to the length of Olea pollen season. However, the best correlation coefficient (0.97*) was reached with the variable temperature minimum on days 51-90. Also the rain and minimum temperature from days 10-30 from January 1st have a significant positive correlation with the length of the Olea pollen season meanwhile the maximum temperature from the days 10-30 from January 1st has a negative significant relationship.

5.1.3 The Urticaceae pollen season

The Pearson correlations between the meteorological variables and the start date of Urticaceae pollen season has shown that the best variable to predict the start of the Urticaceae pollen season is the temperature maximum mean on days 1-30 from 1st of January. The correlation coefficient obtained for this variable was -0.99**. This variable (table. 13) was used later for the linear regression to predict the start date of Urticaceae pollen season.

Also the rain days from 1-40 from January 1^{st} have a negative significant correlation with the start of Urticaceae pollen season. The same correlation was found with the cumulative rain from days 1-40 from January 1^{st}. This could be interpreted as an effect in which the more rain that falls during January and the first ten days of February the earlier the start of Urticaceae pollen season will be.

Factors influencing the Urticaceae pollen season have been described by many authors [D'Amato *et al.*, 1992, Gioulekas *et al.*, 1991; Fornaciari *et al.*, 1992]. It is known that the anthers of Parietaria open during favourable weather, particularly when it is warm and dry. They tend to open during daylight hours, from early morning to late afternoon. However in the case of the Urticaceae family, pollen liberation involves an explosive mechanism. Urticaceae stamens are normally bent, but when temperature and humidity conditions are suitable, they rise to the upright position and release their pollen grains. The pollen release, transportation and dispersal in the air, are closely linked with atmospheric phenomena. There have been several studies on the influence of meteorological parameters on the pollen concentrations of Urticaceae family but not many on the characteristics of Urticaceae pollen season.

Also the same negative significant correlation was found between the rain days from days 40-100 from January 1^{st} and the end of the Urticaceae pollen season. In this case the more rain falling during the mentioned period the earlier the end of Urticaceae pollen season will be.

The variable rain mean from days 91-120 from 1^{st} of January achieved the highest correlation coefficient (-0.99**) with the end date of Urticaceae pollen season. This variable was used to enter to the linear regression to predict the end date of Urticaceae pollen season.

Also the cumulative maximum temperatures from days 61-120 from January 1^{st} have a positive significant correlation with the end of the Urticaceae pollen season. Also it was found that the mean minimum temperature from days 11-50 from January the 1^{st} has a negative significant correlation with the end of the Urticaceae pollen season.

The variable maximum temperature on days 91-120 from 1st of January reached the highest correlation coeffient (0.99*) with the severity of Urticaceae pollen. This variable was enter to the linear regression to predict the severity of Urticaceae.

Also the positive significant correlation was found between the rain days from 41-100 from January 1st and the severity of Urticaceae pollen season. In this case the more rain produced during the period from middle of February till May the higher the total pollen production.The maximum temperature from days 81-120 has a negative significant correlation with the severity of Urticeaceae pollen season. The variable total rainfall on days 61-90 from 1st of January has the highest correlation coefficient (-0.98*) with the length of Urticaceae pollen season. The coefficient is negative that means that the more rain falls during days 61-90 the shorter the Urticaceae pollen season. This variable was entered to the linear regression to predict the length of Urticaceae pollen season.

Also the rain days from days 41-90 have a negative significant correlation with the length of Urticaceae pollen season. In this case if more rain will be produced from the days 41-90 the length of the Urticaceae pollen season will be shorter.

The cumulative maximum temperatures from days 31-60 (February-till March) have also a positive significant correlation with the length of Urticaceae pollen season. If the cumulative maximum temperatures from February until March are higher the length of Urticaceae pollen season will be shorter.

Table 13 Significant correlations between start and end of Urticaceae pollen season (Method 5%) and meteorological variables in Tirana during the four years study

		Correlation coefficient	
Start	Rain days from 1-20 from Jan 1st	*-0.955*	*
	Rain days from 1-40 from Jan 1st	*-0.956*	*
	Rain mean days from 10-30 from Jan 1st	*-0.978*	*
	Rain mean days from 10-40 from Jan 1st	*-0.982*	*
	Cumulative Rain days from 11-20 from Jan 1st	*-0.953*	*
	Cumulative Rain days from 31-40 from Jan 1st	*-0.955*	*
	Cumulative Rain days from 21-40 from Jan 1st	*-0.955*	*
	Cumulative Rain days from 1-40 from Jan 1st	*-0.955*	*
	Maximum temperature mean from days 1-30 days from Jan 1st	**0.997**	**

End	Rain days from 41-50 from Jan 1st	*0.959*	*
	Rain days from 81-90 from Jan 1st	*-0.969*	*
	Rain days from 81-100 from Jan 1st	*-0.967*	*
	Rain days from 41-80 from Jan 1st	*-0.999*	*
	Rain mean days from 91-120 from Jan 1st	***-0.998***	**
	Rain mean days 51-90 from Jan 1st	*-0.996*	**
	Minimum temperature days from 1-50	*-0.980*	*
	Minimum mean temperature mean from days 10-50 from Jan 1st	*-0.995*	*
	Maximum temperature mean from days 91-110 from Jan 1st	0.982	*
	Cumulative maximum temperature from days 91-100 from Jan 1st	0.979	*
	Cumulative maximum temperature days from 101-110 from Jan 1st	0.969	*
	Cumulative maximum temperature days from 111-120 from Jan 1st	0.955	*
	Cumulative minimum temperature days from 81-100 from Jan 1st	0.976	*
	Cumulative maximum temperature days 101-120 from Jan 1st	0.955	*
	Cumulative maximum temperature days 91-120 from Jan 1st	0.951	*
	Cumulative maximum temperature days 81-120 from Jan 1st	0.955	*
	Cumulative maximum temperature days 51-100 from Jan 1st	0.976	*

*** Correlation is significant at the 0.05 level (2-tailed).**
**** Correlation is significant at the 0.01 level (2-tailed).**

Table 14. Significant correlations between severity and length of Urticaceae pollen season (Method 5%) and meteorological variables in Tirana during the four years study

		Correlation coefficient	
Severity	Rain days from 51-100 from Jan 1st	0.964	*
	Rain mean days from 51-70 from Jan 1st	0.953	*
	Rain days from 81-90 from Jan 1st	0.998	*
	Rain days from 61-90 from Jan 1st	0980	*
	Rain mean days from 41-70 from Jan 1st	0.981	*
	Rain mean days from 51-70 from Jan 1st	0.953	*
	Maximum temperature days from 141-150 from Jan 1st	0.950	*
	Maximum temperature days from 81-100 from Jan 1st	*-0.974*	*
	Maximum temperature days from 91-120 from Jan 1st	*-0.969*	*
	Maximum temperature days from 91-110 from Jan 1st	*0 .997*	*
	Maximum mean temperature days from 131-170 from Jan 1st	0.998	*
	Cumulative maximum temperature days from 41-50 from Jan 1st	0.961	*

Length	Rain days from 41-50 from Jan 1st	*-0.992*	*
	Rain days from 81-100 from Jan 1st	*-0.966*	*
	Rain mean days from 71-90 from Jan 1st	*-0.998*	*
	Rain from days 61-90 from Jan 1st	**- 0.989**	*
	Minimum temperature days from 1-50 from Jan 1st	*-0.979*	*
	Minimum temperature days from 10-50 from Jan 1st	*-0.966*	*
	Cumulative maximum temperature days from 51-60 from Jan 1st	0.980	*
	Cumulative maximum temperature days from 41-60 from Jan 1st	0.986	*
	Cumulative maximum temperature days from 31-60 from Jan 1st	0.986	*

* **Correlation is significant at the 0.05 level (2-tailed).**

** **Correlation is significant at the 0.01 level (2-tailed).**

CHAPTER SIX: SECTION ONE
LONG TERM FORECAST MODELS FOR GRASS POLLEN

A wide range of meteorological variables were considered in correlation analysis in chapter five in order to determine which of the weather parameters give the best explanations of the main features of the pollen season.

Correlation analysis is used to measure the strength and the direction of the linear relationship between two variables. Following this, simple linear regression was used to investigate the relationship between the environmental variables and the start, severity and the end dates of pollen season for the mentioned study years. A number of variables were examined for possible inclusion in the linear regression. The selection of such variables was chosen after consulting other studies made by different authors. In the forecasting of the start of the grass pollen season the parameters used were daily average temperatures as monthly means, ten days means, twenty day means, the total monthly precipitation, ten day means, twenty day mean rainfall etc (appendix B1). The variables that gave the highest correlation were included in the model. It was decided to use one method for the start and the end of the grass pollen season: the 5% method. By this method the grass pollen season start dates were defined as the 5% of the cumulative seasonal total and the end date was defined at 95% level [Pathirane, 1975 ;Trigo *et al.,* 1996]. The initial and final the 5% of the annual curve were eliminated to avoid a lengthy tail-off. Although various criteria are in use for defining the start date, the 5% method was chosen due to relatively low airborne pollen concentrations in the atmosphere of Tirana. The length of the grass pollen season is considered as equal to the number of days between the start and end date of grass pollen season while severity is characterized by the total yearly grass pollen count.

The start of peak period was defined as Pathirane, 1975 in which the cumulative percentages of daily pollen counts were graphically depicted and the main period of pollen release lies between the inflections of a sigmoid curve. The end of peak period was defined when 80% of the grass pollen release was recorded [Smith & Emberlin, 2005]. The peak value date was considered the day when the maximum of grass pollen concentrations was recorded in the air.

6.1 START OF THE GRASS POLLEN SEASON

The grass pollen season in Tirana for the four years of study usually started at the beginning of May. The range in the difference in the start of the grass pollen season with 5% method was 20 days. The earliest start day was registered in 2002 (day 113). Looking at the weather characteristics of this year, it was noted that the mean temperature maximum for the months February, March and April were respectively 16.1°C,18.3°C and 19.3°C which were the highest compared with the same months in the other years. Also the year 2002 was the year when the rainfall was noted in very small amounts in these months.

The latest start of the grass pollen season was registered in 1996 at 133 days from the 1st of January. The spring of 1996 was characterized by lowest temperature maximum mean in February and March respectively 12°C and 13°C compared with the others study years which explain the latest start of the grass pollen season observed in this year. It should be noted that the months of March in 1996 was characterized by abundant rainfall reaching a value of 214mm. Also the January and February were characterized by lack of rainfall respectively 9 and 7mm in total. Appendix U 6.1, 6.2, 6.3 and 6.4 shows the accumulated rainfall mean and the temperature maximum mean in the years of study.

Firstly a model was developed using the framework of Pearson correlation to determine which environmental variables have the most significant impact on the grass pollen count (Appendix B). Then this model was used in an attempt to predict the start of the pollen season using the simple linear regression models. It should be mentioned that 10 day aggregated variables gave the highest level of explanation. The mean temperature maximum between the days 61-70 starting from the 1st of January, which correspond to the period of 2-12 March was among thirteen chosen variables which gave the best explanation of the start of grass pollen season with the meteorological variables. The correlation coefficient was -0.99**, that means that the higher the temperature mean gets the earlier the start of the pollen season start. Then the variable Tmax mean 60-70 was entered into the simple linear regression in order to predict the start of the grass pollen season in Tirana.

The simple linear model predicted the start date of the grass pollen season achieved 98.4% of the explanation, having the Adjusted R Square= .976 (Appendix H1: under the table Model Summary)

The simple linear regression is shown below.

Start day of grass pollen= 152.632- (1.956 X Temp Max mean on days 61-70)

Table 15 Accuracy of the model predicting the start date of the grass pollen season

Year	Predicted start of the grass pollen season (nr of days from 1st of January)	Actual start of the grass pollen season (nr of days from the 1st of January)
2003	121	124
2004	131	113

The predicted model enabled the start of the grass pollen season to be forecast with 98% accuracy in 2003 and 86% in 2004 when the 5% method was used.

Also the predicted model it is likely to be applied easily in Tirana as the meteorological variable required (Tmax men 61-70 from the first of January) could be used easily before the grass pollen season start. The result achieved from the model to predict the grass pollen season agreed with the same work different authors achieved that the temperature close the start of the pollen season appeared to determinant in constructing models for the start of the grass pollen season [Frenguelli *et al.,* 1989].

6.2 THE END OF THE GRASS POLLEN SEASON

The same basic meteorological variables were used to forecast the end of grass pollen season (Appendix B). The end dates chosen were the 95% method. The method used has been described earlier in this chapter.

The earliest end of the grass pollen season with the method 95% was the year 1996 and the latest end of the grass pollen season was the year 1998. As it will be described below, the coefficient correlation achieved by the Pearson correlation shows a positive correlation (r =0.990*) that means the lack of the rainfall gives a shorter grass pollen season and vice versa. It was decided that the variable rain mean days 11-20 was the best to be used in forecasting the end of the grass pollen season, a linear regression model was performed. Using the linear regression model a R square=0.980* was achieved with Adjusted R Square=0 .970 (Appendix H2– Model summary).

The simple linear regression is shown below.

End day of the grass pollen season= 195.972+ (0.779 X rain days mean on day 11-20)

Table 16 Accuracy of the model predicting the end date of the grass pollen season

Year	Predicted end of the grass pollen season (nr of days from 1st of January)	Actual end of the grass pollen season (nr of days from the 1st of January)
2003	197	174
2004	198	223

The predicted model enabled the end date of the grass pollen season to be forecasted with 88% accuracy in both years when the 95% method was used. The difference between the predicted end date of the grass pollen season and the actual date was with the range of 22 days difference.

6.3 SEVERITY OF THE GRASS POLLEN SEASON

In order to forecast the severity of the grass pollen season the same basic combination of the meteorological parameters were used as for the start and the end of the grass pollen season (Appendix B). Using the framework of the correlation analysis only one meteorological parameters was significant (Rain mean on days 121-160). The coefficient obtained from the Pearson coefficient was r=0.964*. That means that the more rain that occurs on the days 120-160 the more grass pollen count will be in the atmosphere. It seems that the mean rain days on the May do contribute to the severity of the grass pollen season**.** This agrees with other studies emphasizing the role of the weather conditions during the late spring when the pollen forms in the anthers with the severity of the grass pollen season. The variable rain days mean on 121-160, was entered into the simple linear regression in order to obtain a model to forecast the severity of the grass pollen season.

The simple linear regression predicted the severity of the grass pollen season achieved 82% of explanation, having the Adjusted R Square =0.970 (Appendix H3: Model Summary)

The simple linear regression is shown below.

Severity of the grass pollen season= 3529.228-(464.073 X mean rain days on 121-160)

Table 17 Accuracy of the model predicting the severity of the grass pollen season

Year	Predicted severity of the grass pollen season (nr of days from 1st of January)	Actual severity of the grass pollen season (nr of days from the 1st of January)
2003	3065	2511
2004	2009	1487

The predicted model enabled the severity of the grass pollen season to be forecast with 81% accuracy in 2003 and 74% in 2004.

6.4 LENGTH OF THE POLLEN SEASON

In order to forecast the length of the grass pollen season the same basic meteorological variables were used as for the start, end and severity of the grass pollen season.

All these meteorological parameters were used on the correlation analysis and the variables with the highest coefficient correlation were used on the simple linear regression (Appendix B). It seems that the Temperature maximum on the first ten days of February do influence the length of the grass pollen season. The higher the temperature mean on this period the longer the length of the grass pollen is. Using the data of the study years it should be noted the shortest of the grass pollen seasons was the year 1996 (63 days) and the longest one was the year 2002 (84). The year 1996, was the year when the start of the grass pollen season was latest compared with the year 2002, when the start of the grass pollen season was the earliest one through the four years of our study.

Using the simple linear regression the variable Tmax mean on days 41-50 achieved the highest Adjusted R Square=0 .996 (Appendix H4 : Model Summary)

The simple linear regression which predicted the start date of the grass pollen season achieved the 77% of the explanation.

The simple linear regression is shown below.

Length of the grass pollen season= 18.832+ (3.806 X Tmax mean on days 41-50)

Table 18 Accuracy of the model predicting the length of the grass pollen season

Year	Predicted length of the grass pollen season (nr of days from 1st of January)	Actual length of the grass pollen season (nr of days from the 1st of January)
2003	56	73
2004	53	110

The predicted model enabled the length of the grass pollen season to be forecast with 77% accuracy in 2003 and 48% in 2004.

6.5 START DAY OF PEAK PERIOD FOR GRASS POLLEN SEASON

To forecast the start day of peak period for grass pollen season the same combination of the meteorological variables were used as for other features of the main grass pollen season (Appendix B1).

Comparing the start day of the peak period for grass in the study years it was observed that in 2002 and in 1998 the peak period was earlier (day 135 in both years) compared with 1995 (day 137) and with 1996 (day 139).

All the combinations of meteorological parameters were used in the correlation analysis and the variables with the highest coefficient correlation were used in the simple linear regression. It seems that the variable temperature minimum on days 1-50 starting from the 1st of January does influence to the start of the peak period of the grass pollen season. The correlation analysis showed a positive correlation with this meteorological variable.

Using the simple linear regression the variable temperature minimum on days 1-50 achieved the highest Adjusted R Square=0 .967and R square=0.978 (Appendix H5: Model Summary).

The simple linear regression predicted the start day of the peak period for the grass pollen season achieved the 97.8 % of the explanation.

The simple linear regression is shown below

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Start day of the peak period for grass pollen = 116.268 + (5.122 X temp min mean on days 1-50)

Table 19 Accuracy of the model predicting the start day of peak period for grass pollen

Year	Predicted the start day of the peak period for grass (nr of days from 1st of January)	Actual the start day of the peak period for grass (nr of days from the 1st of January)
2003	131	132
2004	138	135

The predicted model enabled the start day of peak period of the grass pollen to be forecast with 97 % accuracy in 2003 and 99 % in 2004.

6.5.1 START DAY OF PEAK COUNT FOR GRASS POLLEN SEASON

To forecast the start day of peak count for grass pollen season the same combination of the meteorological variables were used as for other features of the main grass pollen season (Appendix B1).

Comparing the start date of the peak count for grass in the study years it was observed that in 2002 the peak value was recorded earlier (day 138) compared with 1995 (day 149), in 1996 (day 147), 1998 (day 142). As it has been explained earlier in this chapter, the year 2002 was a very different year with lower monthly mean temperatures compared with the other years. Also the period between 61-80 days from 1st of January was characterized by lack of rain in 2002 (mean 0-70) compared with the same period 1995 (rain mean =8.80), 1996 (rain mean= 7.10), 1998 (rain mean=3.20).

All these meteorological parameters were used in the correlation analysis and the variables with the highest coefficient correlation were used in the simple linear regression. It seems that the rainfall mean on the period of on the first twenty days of March does influence the peak value of the grass pollen season. The correlation analysis showed a positive correlation with this meteorological variable explaining that if more rain is experienced in this period (days from 61-80 starting from the 1st of January), then a later start of the peak value for grass will be observed.

Using the simple linear regression the variable rain mean on days 61-80 achieved the highest Adjusted R Square=0 .995 (Appendix H6 : Model Summary).

The simple linear regression predicted the start of the peak count for the grass pollen season achieved the 98 % of the explanation.

The simple linear regression is shown below.

Start day of peak count for grass pollen = 137.326 + (1 348 X rain mean mean on days 61-80)

Table 20 Accuracy of the model predicting the start day of peak count for grass pollen

Year	Predicted the start day of peak count for grass (nr of days from 1st of January)	Actual the start day of peak count for grass (nr of days from the 1st of January)
2003	137	139
2004	138	141

The simple linear regression used to predict the day of peak count for grass pollen achieved 98.% accuracy in 2003 and 97.8% accuracy in 2004.

6.6 END OF PEAK PERIOD FOR GRASS POLLEN (80% METHOD)

To forecast the end of the peak period for grass pollen season (method 80%) the same combination of the meteorological variables were used as for other features of the main grass pollen season (appendix B1). The way to calculate this method has been described in the Methodology chapter.

All these meteorological parameters were used on the correlation analysis and the variables with the highest coefficient correlation were used on the simple linear regression. It seems that the mean of the temperature minimum on the period of on the first twenty days of January does influence the end date of peak period of the grass pollen season. The correlation analysis showed a negative correlation with this meteorological variable explaining that lower the mean temperatures minimum will be in this period the earlier the end date of the peak period will be observed. It should be noted that the year 2002 experienced a temperature minimum mean on 1-20 days of -0.04 very different from the other years where in 1995 this variable was 3.5, in 1996 was 2.74 and in 1998 it was 5.83. The start of the peak period in 2002 was registered earlier compared with the other years and also the end date of the peak period with 80% method was later compared with the same years.

Using the simple linear regression the variable Tmin mean on days 1-20 achieved the highest Adjusted R Square=0 .767 (Appendix H7: Model Summary).

The simple linear regression predicted the end peak period of the grass pollen season achieved the 90 % of the explanation.

The simple linear regression is shown below.

End of the the peak date for grass pollen = 173.830 - (1.189 X Tmin mean on days 1-20)

Table 21 Accuracy of the model predicting the end date in peak period for grass pollen

Year	Predicted the end date in peak period for grass pollen (nr of days from 1st of January)	Actual the end date in peak period for grass pollen (nr of days from the 1st of January)
2003	133	149
2004	112	183

The predicted model enabled the end of peak period of the grass pollen season to be forecast with 89.2 % accuracy in 2003 and 61 % in 2004.

6.6 APPRAISAL OF LONG-TERM FORECAST MODELS FOR GRASS IN TIRANA

Forecast models for grass for some characteristics of the pollen season have been constructed using daily grass pollen and meteorological variables from Tirana city.

A lot of meteorological variables were included in the correlation analysis to see which of them gave the best coefficient correlation.

For the start of the pollen season the variable temperature mean maximum on days 61-70 gave the best explanations (the first ten days of March). It has been mentioned by many authors that the meteorological factors, especially temperature maximum in March and April do influence the start of the grass pollen season [Frenguelli *et al.,* 1989].

The model was built using four years of data and tested in the years 2003 and 2004.

The start of grass pollen season used the method with 5% and the end with 95%.The explanations of this method have been given in the methodology chapter.

The model was able to forecast the start of the grass pollen season with 98% accuracy in year 2003 and 86% accuracy in year 2004. In the year 2003 the difference between the predicted and actual date of the start of the grass pollen season was 3 days while in year 2004 was 18 days difference.

By using a wide range of meteorological variables through correlation analysis it was found that the variable rain days mean on day 11-20 gave the best explanations to predict the end of the grass pollen season. The explanations of the choice of the end of the grass pollen season have been given in the Methodology chapter.

When the model was tested in 2003 and 2004 the accuracy obtained was equal to 88.8% for both years. The difference between the predicted and actual date for the end of the grass pollen season was 22 days for year 2003 and 25 days for year 2004.

The same meteorological variables as for start and end of the pollen season were used to predict the severity of the grass pollen season.

The correlation analysis has shown that the variable mean rain on days 121-160 was the best variable to predict the severity of the grass pollen season. This means that the mean rainfall during the May and the first ten days of June do influence the total number of the grass pollen in Tirana area.

When the model was tested in the year 2003 and 2004 the accuracy was better in year 2004 then 2003. The difference of the total grass pollen was 517 for year 2004 and 554 for year 2003.

Through the correlation analysis, it was shown that the variable Temperature maximum on days 41-50 was the best variable to explain the length of the grass pollen season. That means that the temperature maximum on the first ten days of February does influence the length of the grass pollen season.

When the model was tested in the years 2003 and 2004 the model achieved accuracy of 76.7% for the year 2003 with a difference of 17 days between the predicted and actual length of the grass pollen season and a difference of 57 days in year 2004.

The explanations of the defining the start and end of peak period have been given in the methodology chapter.

The best variable to predict the start of the grass period was rain mean on days 61-80 and the accuracy achieved was 98.5% for the year 2003 and 97.8% for the year 2004.

The difference between the predicted and actual date of the start of the peak period for grass was 2 days in year 2003 and 3 days in year 2004.

Through the correlation analysis, it was shown that the variable Temperature minimum on days 1-50 was the best variable to explain the start day of pollen count for grass pollen season. That means that the temperature minimum during the January and first two weeks of February does influence the day when the maximum grass pollen count will be recorded.

When the model was tested in the years 2003 and 2004 the model achieved accuracy of 97% for the year 2003 with a difference of one day between the predicted and actual day of the maximum value for grass and a difference of three days in year 2004.

The variable that gave the best explanations for the end of the peak period for grass was temperature minimum on days 1-20, the first twenty days of January.

When the model was tested in year 2003 and year 2004, it gave an accuracy of 89.2% for year 2003 and 61% for the year 2004. The difference between the forecast and actual dates of the end of the grass peak period was 16 days for year 2003 and 71 days for year 2004.

Overall a satisfactory level of explanation has been achieved in the models such that they will have a practical use in pollen forecasting. The accuracy achieved by the predictions indicates that the models can be used in future years in actual forecasting situations.

CHAPTER SIX: SECTION TWO
DEVELOPING SHORT TERM FORECAST FOR GRASS POLLEN IN TIRANA

The short term daily forecast model for grass pollen in Tirana was constructed for three different periods of the grass pollen season, pre-peak, peak and post-peak. The methodology of the way in which the three periods were divided has been described in the chapter 4.

Three regression models were constructed as follows:

1. Multiple regression model in order to forecast the daily variation of grass pollen counts during pre-peak period
2. Multiple regression model in order to forecast the daily variation of the grass pollen counts during the peak period
3. Multiple regression model in order to forecast the daily variation of the grass pollen counts during the post- peak period

Pollen data were square rooted (normalized) as it was found to be not normally distributed [Jones, 1995]. The "square root" transformation is usually used when the data to be transformed is obtained by counting [Toro *et al.,* 1998]. The square rooted data reduces the relative error (or coefficient of variation) without modifying significantly the importance of the relative variance [Galan *et al.,* 1995]. In this research it was easier for the data to be normalized rather than standardized as the standardized data need the total pollen count to be forecast in order to convert the predicted model into the forecast model which will complicate the process of constructing models for grass pollen. All the data were checked to see if it was normally distributed. Normal is used to describe a symmetrical, bell shaped curve, which has the greatest frequency of scores in the middle, with smaller frequencies towards the extremes [Graveter & Vallnau, 2000].

The results achieved should be treated with the caution due to the small data set (4 years). Also the outliers were detected as the statistical analysis used by this research

(SPPS) is sensitive to outliers. An outlier is a case with an extreme value on one variable or a strange combination of scores in two or more variables that distort statistics [Pallant., 2002]. Many outliers were found especially for rainfall and an attempt was made to square root the data in order to “clean” the data before entering it into the multiple regression. It was then decided to leave outliers in order to forecast them when the models will be constructed.

Also the Kruskal- Vallace test was used to determine if the grass pollen season should be treated as a separate population. The Kruskal- Vallace is a nonparametric test and allows the comparision of the scores on some continuous variables for three or more groups [Pallant., 2002].

The results of the Kruskal-Vallace nonparametric test showed that a significant difference exists between the mean ranks of the grass pollen count during the periods of pre-peak, peak and post-peak. This result allows these three periods to be treated as separate populations while the forecast models need to be constructed.

Correlation analyses were performed to establish the strength and the direction of the relationship between the dependent and independent variables before their entrance into the multiple regression model.

From the third year of the research it is was possible to obtain the wind direction and wind data from the Airport station of Tirana, which is situated 40km far from the pollen trap site in Tirana. It was decided to examine the wind data, to determine if there is any pattern in relation to the pollen data. Analysis of variance compares the variance (variability in scores) between the different groups (believed to be due to the independent variable) with the variability within each of groups (believed to be due to chance)[Pallant, 2002]. The wind direction data was divided into grades, so it was separated into different groups in order to obtain equal sizes between groups. Using the Kruskal- Vallace test, different regroups were used. All the results achieved from this test were negative, except the wind direction and wind speed in the peak period (Appendix X1-X4). Analysis of variance through the Kruskal Vallace test showed that there is a significance difference between the wind parameters and daily grass pollen count during the peak period. The correlation analysis between the grass pollen season and wind parameters showed that the correlation coefficient was not statistically significant therefore this variable was discarded and not used for the multiple regression.

The relationship between daily grass pollen counts and the pollen count during the preceding days was explored in the framework of the correlation analysis. The 5, 4, 3 and 2 day running mean of the normalised grass pollen counts were used in the correlation to compare with the normalised daily grass pollen count. It was found that a strong positive correlation signifies that the amount of the pollen counts present during the previous days will be likely to continue. This method has been used by many authors and has proved successfully [Emberlin., 1997; Smith& Emberlin, 2005]. Besides these variables, the temperature maximum, minimum and rainfall were used to build up the forecast models for the grass pollen.

The multiple regressions were carried out for each period in order to construct models for daily grass pollen. Simple linear regression was used for the post-peak period, since the correlation analysis showed a significance difference with only one meteorological parameter.

The next step was to convert all the forecast models obtained from the equation to the normal work scale (p/m^3). Predicted values were squared and tested with the actual daily grass pollen counts from the 2003 season. As it is first time of this kind of research has been done in Albania, the threshold of countries with the similar climate to Albania were consulted .It was decided to use the threshold for grass pollen as used in Italy (Tab 22) as this fits with the pattern and severity of grass pollen in Albania.

Table.22. Threshod used for forecasted daily pollen counts in Tirana

Grass pollen counts(p/m3)	Threshold used	Numerical score
1-9	low	1
10-29	moderate	2
30-100	high	3
≥ 101	extra high	4

Predicted grass pollen counts were compared with the real (observed) data obtained by means of the non parametric test in order to specify if the models were strong enough to predict the trends of the grass pollen counts.

6.8 DAILY MULTIPLE REGRESSION MODEL FOR THE PRE-PEAK PERIOD OF THE GRASS POLLEN SEASON IN TIRANA

The meteorological variables used to forecast the daily grass pollen count during the pre-peak period were 4-days running mean (0.705**) and temperature maximum (0.261*). These two meteorological variables were obtained through using the Pearson correlation (Appendix J2). These two variables were used to construct a model for daily grass pollen season during the pre-peak period.

Before constructing the model a checking system for assumptions was performed.

6.8.1. Multicollinearity

The correlations between the variables in the model were provided in the table labeled Correlations (Appendix J1**)**. The relationship between the independent variable and the dependent variable show a clear relationship. The correlation between two independent variables was checked to see if was high. Tabanich and Fidell [2001] suggest thinking carefully if two variables have a bivariate correlation of 0.7 or more in the same analysis. In this case the correlation was 0.277.

SPSS performs "collinearity diagnostics" as the part of the multiple programm. This is presented in the table labeled Coefficients**.** The column headed "Tolerance" was checked in case a value very low is detected as this presumes the possibility of multicollinearity. In this case the value was 0.923 therefore this value did not appear to have violated the assumption.

6.8.2. Outliers, Normality, Linearity, Homoscedascity, Independence of Residuals

As Pallant, 2002, suggests one way that these assumptions could be checked is by observing the residual scatterplot and the Normal Probability Plot of the regression standardized residuals that are able to run though the SSPS analysis. In the Normal

Probability Plot it is desirable that the points lie in a straight diagonal line from bottom left to top right. This suggests that there are no major deviations from the normality. In the Normal Probability Plot there is a slight deviance from the diagonal line. In the Scatterplot of the standardized residuals it is desirable that the residuals should be roughly rectangular distributed, with most of the scores concentrated in the centre (Along the 0 point). In this model there is a slight deviance from all above mentioned. Outliers could be checked through observing the Mahalanobis distances which are obtained through the multiple regression program. In order to identify which cases are outliers it has been suggested determining the critical Chi-square, using the number of independent variables as the degree of freedom. Using the Pallant, 2002, the critical value for the model with two independent variables is 13.82. Only one outlying number (ID number 35) with a value of 14.1 has been found (Appendix J3). This is common problem as it is not unusual for a few outliers to appear.

6.8.3. Evaluating the model

The most important point in this step is the Model Summary box and the value given under the heading R Square (appendix J1). This value helps to understand how much of the variance in the dependent variable (normalized grass pollen) is explained by the model. The R square obtained by the model is 0.502. Expressed as a percentage, the model has explained 50% if the variance in the daily grass pollen during the pre-peak period.

Pallant, [2002] suggests that when a small data set is involved an adjusted R Square value provides a better estimate of the true population as the R square tends to be overestimation of the true value in the population. The model has a value of Adjusted R Square of 0 .490.

Under the coefficient table the column marked Significance should be checked. Two days running mean made a significant unique contribution to the prediction of dependent variable.

The sample size also was observed for the pre-peak period. Tabanich *et al.,* [2001] suggest that the size requirements when a multiple regression is performed is $N \geq 50 + 8m$

(where m- independent variables), this model had 90 cases and fits to the authors requirements.

The forecast model for the daily grass pollen during the pre-peak period is shown in fig.14.

Predicted daily grass pollen = 0.379+ (0.095 x two-day) + (0.078 x Tmax)

The predicted and actual daily grass pollen counts were converted into numerical scores as explained earlier in this chapter. Percent accuracy obtained was 69% in 2003 and 29% in 2004. Then the predicted and actual grass pollen counts were subjected to correlation analysis. The constructed model was able to predict the pattern of daily grass pollen counts during the pre-peak period. Through using the Excel program the actual and predicted grass pollen counts were performed for 2003 and 2004 (Fig. 14,15).

Fig.14

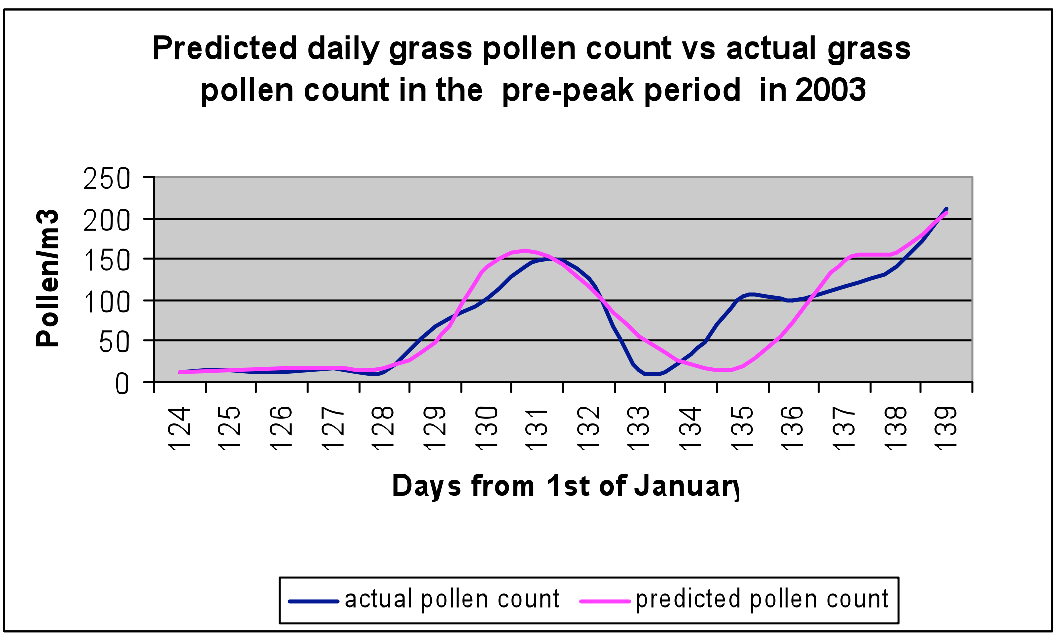
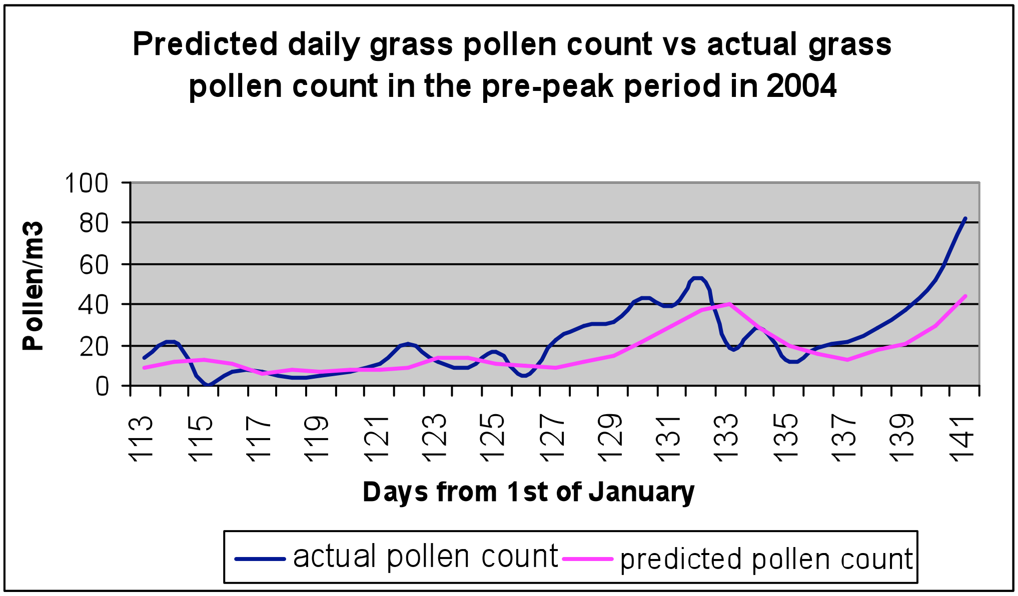


Fig.15



6.9 MULTIPLE REGRESSION MODEL FOR THE PEAK PERIOD OF THE GRASS POLLEN SEASON IN TIRANA

The meteorological variables used to forecast the daily grass pollen counts in the peak period were 5-days running mean and temperature minimum. The Pearson coefficient table shows the coefficient value obtained for those two meteorological variables (Appendix J4).

As it was described in 6.8, before the model will be constructed some checking system are required.

6.9.1 Multicollinarity

The correlation between the independent variables is -0.363, less than 0.7 therefore all the variables will be retained in the model (Appendix J4).

The value under the column Tolerance is 0 .869, not low so the model has not violated the assumption.

6.9.2 Outliers, Normality, Linearity, Homoscedascity, Independence of Residuals

Through the observing of the Normal Probability Plot there are no major deviations from normality. In the Scatterplot box, most of the scores are concentrated in the center.
Outliers have been detected through the Mahalanobis distances produced by the multiple regression programm. The critical chi- value for two independent variables is 13.82, the model has only one outlying case (ID 45) with a value 14.3 (Appendix J6)

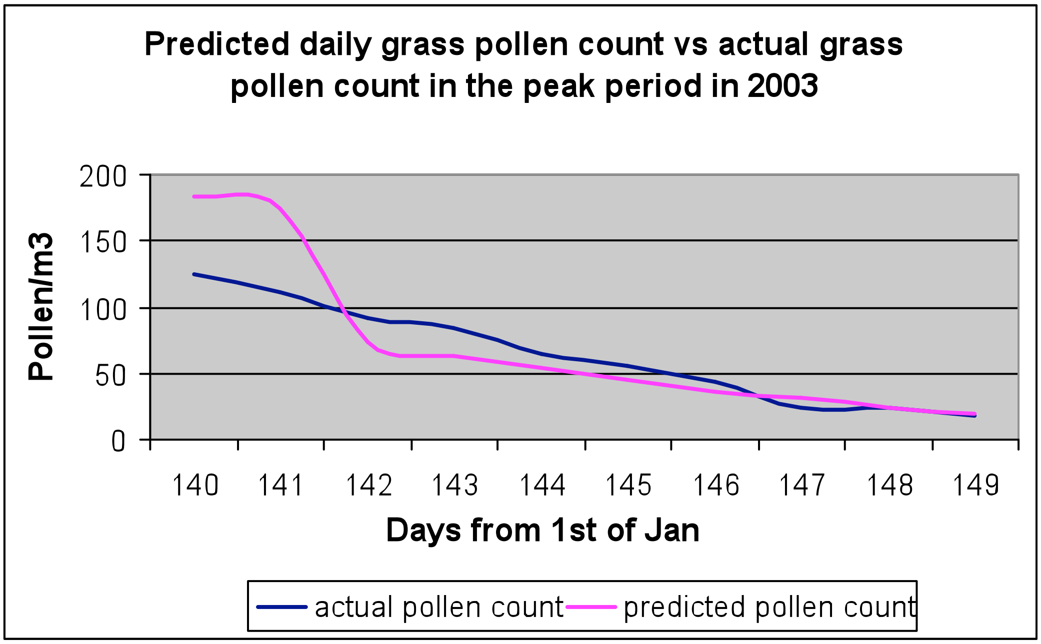
6.9.3 Evaluating the model

The R square under the Model summary box (Appendix J4) has a value of 0.40, therefore the model for the daily grass pollen count during the peak period achieved app 40% of explanation. Adjusted R Square has a value of .391. Under the table coefficients the Beta value are larger for five- days running mean than the temperature minimum.
The sample size for the peak period fulfills the requirement from Tabanich *et al.,* 2001 with 103 cases.

Predicted daily grass pollen = 0.859+ (0.068 x five-day)- (0.091x Tmin)

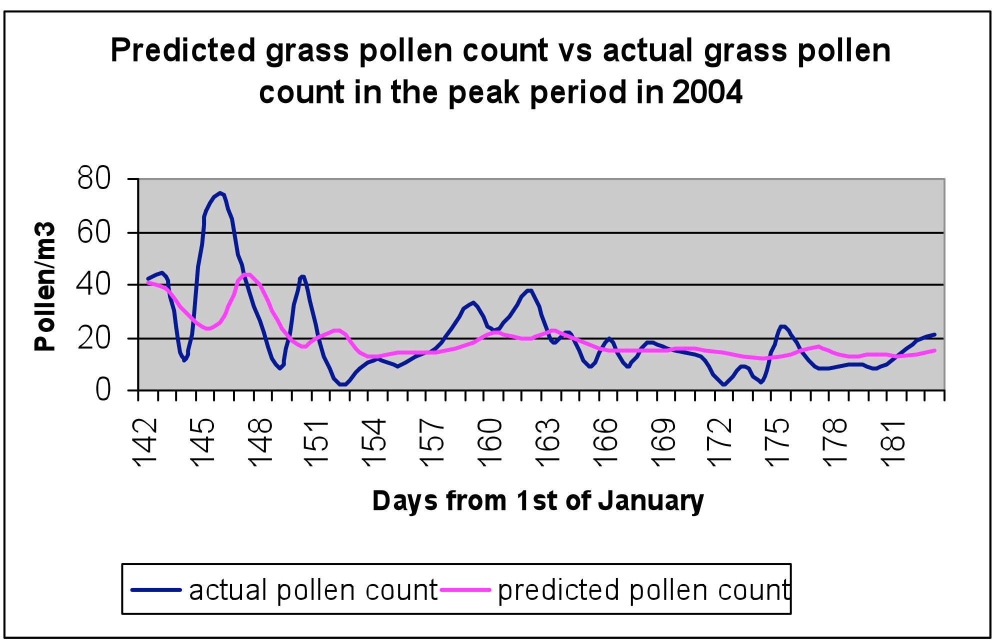
The predicted and actual daily grass pollen counts were converted into numerical scores. Percent accuracy obtained was 90% in year 2003 and 68% in 2004. All the numerical score in the observed pollen count were the same with the actual pollen count except one day. Then the predicted and actual grass pollen count were subjected to correlation analysis to check if the constructed model was able to predict the pattern of daily grass pollen counts during the pre-peak period. The constructed model was able to predict the pattern of daily grass pollen counts during the pre-peak period.
Through using the Excel program the actual and predicted grass pollen count were performed for 2003 and 2004 (Fig. 16, 17).

Fig.16



Predicted daily grass pollen count vs actual grass pollen count in the peak period in 2003
Pollen/m3
200
150
100
50
0
140
141
142
143
144
145
146
147
148
149
Days from 1st of Jan
actual pollen count
predicted pollen count

Fig.17



Predicted grass pollen count vs actual grass pollen count in the peak period in 2004
Pollen/m3
80
60
40
20
0
142
145
148
151
154
157
160
163
166
169
172
175
178
181
Days from 1st of January
actual pollen count
predicted pollen count

6.10 MULTIPLE REGRESSION MODEL FOR THE POST- PEAK PERIOD OF THE GRASS POLLEN SEASON IN TIRANA

The meteorological variables used to forecast the daily pollen counts were two days running mean and temperature minimum. This relationship was found when the Pearson correlation was performed (Appendix J8). The model was constructed by using two metrological variables detected through the Pearson correlation.
The same checking procedure was used as mentioned in 6.8 and 6.9.

6.10.1 Multicollinarity

Through the observation of the correlation between the independent variables no assumptions were detected.
The value under the column Tolerance is 0.220 therefore the model has not violated the assumption (appendix J7)

6.10.2 Outliers, Normality, Linearity, Homoscedascity, Independence of Residuals

Through the observing of the Normal Probability Plot there are no major deviations from normality. In the Scatterplot box, most of the scores are concentrated in the center
Outliers have been detected through the Mahalanobis distances produced by the multiple regression program. The critical chi- value for two independent variables is 13.82, the model does not have outlying cases (Appendix J9).

3. Evaluating the model

The R square under the Model summary box (Appendix J7) has a value of -210, therefore the model for the daily grass pollen count during the peak period achieved app 21% of explanation. Adjusted R Square has a value of 0.197. Under the table Coefficients the Beta value are larger for two- day running mean than the temperature minimum.
The sample size for the post- peak period fulfills the requirement from Tabanich et al., 2001 with 118 cases.

Predicted daily grass pollen = 3.064+ (0.067 x two-day)- (0.053x Tmin)

The predicted and actual daily grass pollen counts were converted into numerical scores. Percent accuracy obtained was 65% in year 2003 and 87% in 2004. Then the predicted and actual grass pollen count were subjected to correlation analysis to check if the constructed model was able to predict the pattern of daily grass pollen counts during the pre-peak period. The constructed model was able to predict the pattern of daily grass pollen counts during the pre-peak period.

The correlation analysis has shown that the predicted pollen grass during the post-peak period did not predict any trend in the grass pollen. Through using the Excel program the actual and predicted grass pollen count were compared in 2003 and 2004 (Fig. 18, 19).

Fig.18

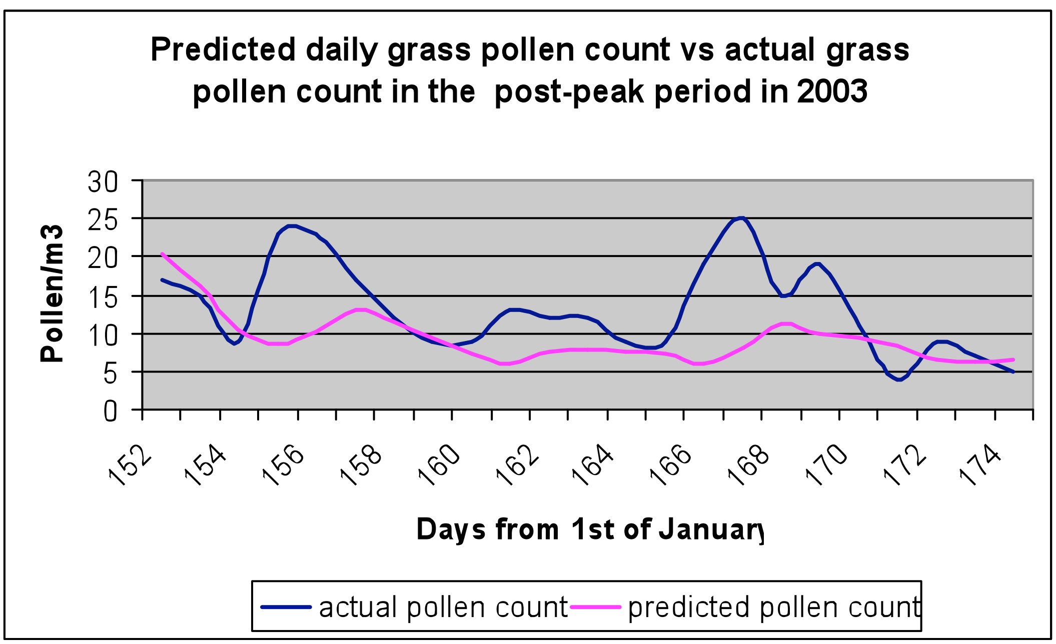
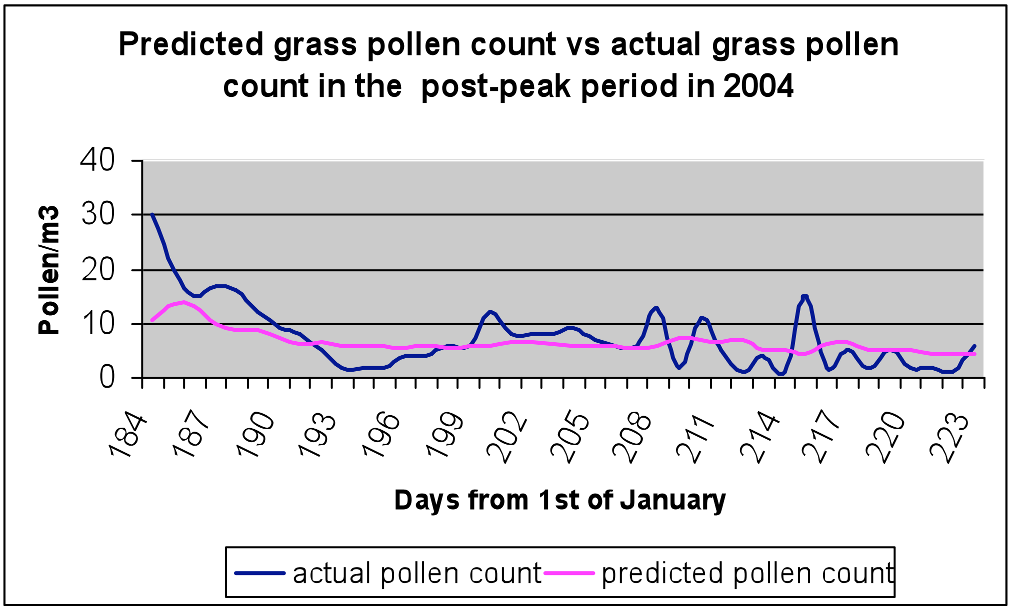


Fig. 19



Predicted grass pollen count vs actual grass pollen count in the post-peak period in 2004
Pollen/m3
40
30
20
10
0
184
187
190
193
196
199
202
205
208
211
214
217
220
223
Days from 1st of January
actual pollen count
predicted pollen count

CHAPTER SIX: SECTION THREE
DEVELOPING SHORT TERM FORECAST MODELS FOR GRASS POLLEN IN TIRANA ON THE NON-RAINY DAYS

Many authors for example, Fornaciari *et al.,* 1992, Emberlin *et al.,* 1991, Trigo *et al.,* 1996) have shown that rainfall has a strong influence on the daily forecast models and this variable can distort the strength of temperature as a parameter in the prediction models. Fornaciari *et al.,* 1992 found that the best correlation was achieved by comparing pollen concentrations and meteorological parameters on the non-rainy days.

The short term daily forecast for grass pollen for the non-rainy days in Tirana was constructed for three different periods of the grass pollen season, pre-peak, peak and post-peak. The methodology of the way in which the three periods were divided has been described in the chapter 4.

Three regression models were constructed as follows:

1. Multiple regression model in order to forecast the daily variation of grass pollen counts during pre-peak period for the non-rainy days
2. Multiple regression model in order to forecast the daily variation of the grass pollen counts during the peak period for the non-rainy days
3. Linear regression model in order to forecast the daily variation of the grass pollen counts during the post- peak period on the non-rainy days.

The same methodology as in the models for the rainy days has been used. The details of this have been given in details in the chapter 6, part two. All the data were checked to see if it was normally distributed.

Also the outliers were detected as the statistical analysis used by this research (SPPS software) is sensitive to outliers. Many outliers were found especially for rainfall and an attempt was made to square root the data in order to “clean” the data before entering it into the multiple regression. It was then decided to leave outliers in order to forecast them when the models will be constructed.

Also the Kruskal- Vallace test was used to determine if the grass pollen season should be treated as a separate population. This result allows these three periods to be treated as separate populations while the forecast models need to be constructed.

The relationship between daily grass pollen counts and the pollen count during the preceding days was explored in the framework of the correlation analysis. The 5, 4, 3 and 2 day running mean grass pollen counts were used in the correlation to compare with the daily grass pollen count for the non-rainy days.

The multiple regressions were carried out for each period in order to construct models for daily grass pollen on the non-rainy days. Simple linear regression was used for the post-peak period since the correlation analysis showed a significance difference with only one meteorological parameter.

All the forecast models obtained from the equation were converted to the normal work scale (p/m^3). Predicted values were squared and tested with the actual daily grass pollen counts from the 2003 and 2004 season. The threshold for grass pollen as used in Italy (Tab 23) was used as this fits with the pattern and severity of grass pollen in Albania.

Table.23 Threshod used for forecast daily pollen counts for the non-rainy days in Tirana

Grass pollen counts(p/m3)	Threshold used	Numerical score
1-9	low	1
10-29	moderate	2
30-100	high	3
≥ 101	extra high	4

Predicted grass pollen counts were compared with the real (observed) data obtained by means of the non parametric test in order to specify if the models were strong enough to predict the trends of the grass pollen counts on the non-rainy days.

6.11 DAILY MULTIPLE REGRESSION MODEL FOR THE PRE-PEAK PERIOD OF THE GRASS POLLEN SEASON IN TIRANA DURING THE NON-RAINY DAYS

The meteorological variables used to forecast the daily grass pollen count during the pre-peak period on the non-rainy days were 2-days running mean (0.767**) and temperature minimum (0.306*). These two meteorological variables were obtained through using the Pearson correlation (Appendix K2)**.** These two variables were used to construct a model for the daily grass pollen season during the pre-peak period on the non-rainy days.
Before constructing the model a checking system for assumptions was performed.

6.11.1. Multicollinearity

The correlations between the variables in the model were provided in the table labeled Correlations (Appendix K1). The relationship between the independent variable and the dependent variable shows a clear relationship. The correlation between two independent variables was checked to see if was high. Tabanick and Fidell [2001] suggest thinking carefully if two variables have a bivariate correlation of 0.7 or more in the same analysis. In this case the correlation was 0.296 (Appendix K1).
SPSS performs "collinearity diagnostics" as the part of the multiple programm. This is presented in the table labeled Coefficients**.** The column headed "Tolerance" was checked in case a value very low is detected as this presumes the possibility of multicollinearity. In this case the value was 0.927 (Appendix K1), therefore this value did not appear to have violated the assumption.

6.11.2. Outliers, Normality, Linearity, Homoscedascity, Independence of Residuals

As Pallant, 2002 suggests one way that these assumptions could be checked is by observing the residual scatterplot and the Normal Probability Plot of the regression standardized residuals that are able to run though the SSPS analysis. In the Normal Probabality Plot it is desirable that the points lie in a straight diagonal line from bottom left to top right. This suggests that there are no major deviations from the normality. In our Normal Probability Plot there is a slight deviance from the diagonal line. In the Scatterplot of the standardized residuals it is desirable that the residuals should be roughly rectangularly distributed, with most of the scores concentrated in the centre (along the 0 point). In this model there is a slight deviance from all above mentioned probably from the outliers obtained in the model. Outliers could be checked through observing the Mahalanobis distances which are obtained through the multiple regression program. In order to identify which cases are outliers it has been suggested determining the critical Chi-square, using the number of independent variables as the degree of freedom. Using the Pallant, 2002, the critical value for the model with two independent variables is 13.82. There is no case that overpasses the mentioned critical value (Appendix K3).

6.11.3 Evaluating the model

The most important point in this step is the Model Summary box and the value given under the heading R Square. This value helps to understand how much of the variance in the dependent variable (normalized grass pollen) is explained by the model. The R square obtained by the model is 0.599 (Appendix K1). Expressed as a percentage, the model has explained 59.9% if the variance in the daily grass pollen during the pre-peak period.

Pallant, [2002] suggests that when a small data set is involved an adjusted R Square value provides a better estimate of the true population as the R square tends to be overestimation of the true value in the population. This model has a value of Adjusted R Square of 0 .586 (Appendix K1).

Under coefficient table the column marked Significance should be checked. Two days running mean made a significant unique contribution to the prediction of dependent variable.

Since the pre-peak period for grass in 2003 was characterized with no rainfall, it was only forecasted the daily grass pollen on the non-rainy days for 2004.

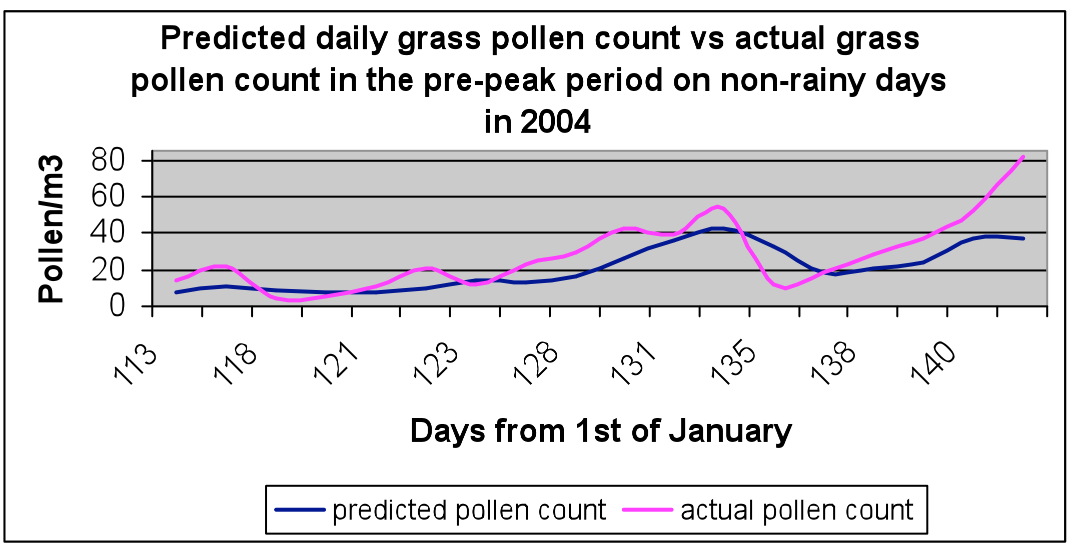
The forecasted model for the daily grass pollen in 2004 during the pre-peak period on the non- rainy days is shown in fig.20.

Predicted daily grass pollen on the non-rainy days =

0.097+ (0.095 x two-day)+ (0.151x Tmin)

The predicted and actual daily grass pollen counts were converted into numerical scores as explained in chapter six. Percent accuracy obtained was 70% in 2004. Then the predicted and actual grass pollen counts were subjected to correlation analysis to check if the constructed model was able to predict the pattern of daily grass pollen counts during the pre-peak period. The constructed model was able to predict the pattern of daily grass pollen counts during the pre-peak period. Through using the Excel program the actual and predicted grass pollen counts were performed for 2004 (Fig. 20).

Fig.20



6.12 MULTIPLE REGRESSION MODEL FOR THE PEAK PERIOD OF THE GRASS POLLEN SEASON IN TIRANA ON THE NON-RAINY DAYS

The meteorological variables used to forecast the daily grass pollen counts in the peak period were 5-days running mean of daily pollen counts and temperature minimum. The Pearson coefficient table shows the coefficient value obtained for those two meteorological variables (Appendix K5).

As described in 6.5 before the model can be constructed some checking system is required.

6.12.1 Multicollinearity

The correlation between the independent variables is 0.483, less than 0.7 therefore all the variables will be retained in the model (Appendix K4).

The value under the column Tolerance is 0.913, not low so the model has not violated the assumption (Appendix K4).

6.12.2 Outliers, Normality, Linearity, Homoscedascity, Independence of Residuals

Through observing the Normal Probability Plot it can be seen that there are no major deviations from normality. In the Scatterplot box, most of the scores are concentrated in the center. Outliers have been detected through the Mahalanobis distances produced by the multiple regression programs. The critical chi- value for two independent variables is 13.82 (Appendix K6), the model does not have any outlined case.

6.12.3 Evaluating the model

The R square under the Model summary box (Appendix K4) has a value of 0.378, therefore the model for the daily grass pollen count during the peak period achieved approximately 37.8% of explanation. Adjusted R Square has a value of 0 .363. Under the table Coefficients the Beta value are larger for two- day running mean than the temperature minimum (Appendix K4).

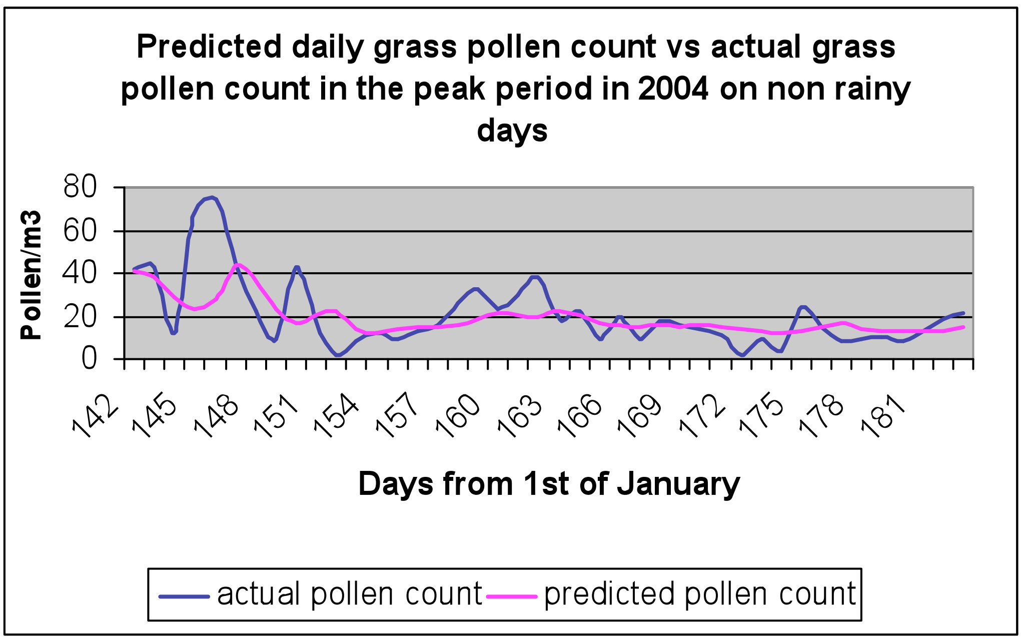
Predicted daily grass pollen for non rainy days =

4.731+ (0.062 x two-day)- (0.101x Tmin)

The predicted and actual daily grass pollen counts on the non-rainy days were converted into numerical scores. The peak period for grass in 2003 was lack of rainfall therefore the model was tested only in 2004. Percent accuracy obtained was 69% in 2004. Then the predicted and actual grass pollen count were subjected to correlation analysis to check if the constructed model was able to predict the pattern of daily grass pollen counts during the pre-peak period on the non-rainy days. The constructed model was able to predict the pattern of daily grass pollen counts during the pre-peak period on the non-rainy days.

Through using the Excel program the actual and predicted grass pollen count were performed for 2004 (Fig. 21).

Fig.21



6.13 LINEAR REGRESSION MODEL FOR THE POST- PEAK PERIOD OF THE GRASS POLLEN SEASON IN TIRANA ON THE NON-RAINY DAYS

The meteorological variable used to forecast the daily pollen counts for the post-peak on the non-rainy days was two days running mean of daily pollen counts. This relationship was found when the Pearson correlation was performed (Appendix K8). The model was constructed by using one meteorological variables detected through the Pearson correlation. In this case a linear regression model was performed.

The same checking procedure was used as mentioned in 6.5 and 6.6.

6.13.1 Multicollinarity

Through the observation of the correlation between the independent variables no assumptions were detected.

The value under the column Tolerance is 1.000 therefore the model has not violated the assumption (Appendix K7).

6.13.2 Outliers, Normality, Linearity, Homoscedascity, Independence of Residuals

Through observing the Normal Probability Plot, it is apparent there are no major deviations from normality. In the Scatterplot box, most of the scores are concentrated in the center. Outliers have been detected through the Mahalanobis distances produced by the multiple regression programm. There are two cases which surpass the critical value of 13.82 (Appendix K9).

6.13.3 Evaluating the model

The R square under the Model summary box (Appendix K7) has a value of 0.323, therefore the model for the daily grass pollen count during the peak period achieved app 32% of explanation. Adjusted R Square has a value of 0.314.

Predicted daily grass pollen for the non-rainy days =

1.917+ (0.082 x two-days running mean)

The predicted and actual daily grass pollen counts for the post peak on the non-rainy days were converted into numerical scores. Percent accuracy obtained was 65% in 2003 and

87% in 2004. Then the predicted and actual grass pollen count were subjected to correlation analysis to check if the constructed model was able to predict the pattern of daily grass pollen counts during the pre-peak period. The constructed model was able to predict the pattern of daily grass pollen counts during the pre-peak period. Through using the Excel program the actual and predicted grass pollen count were performed (Fig. 22, 23).

Fig.22

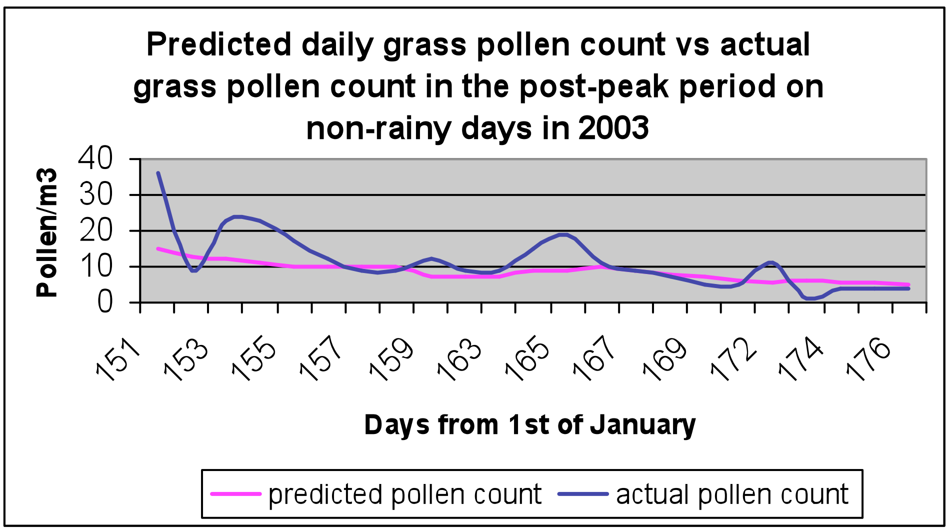
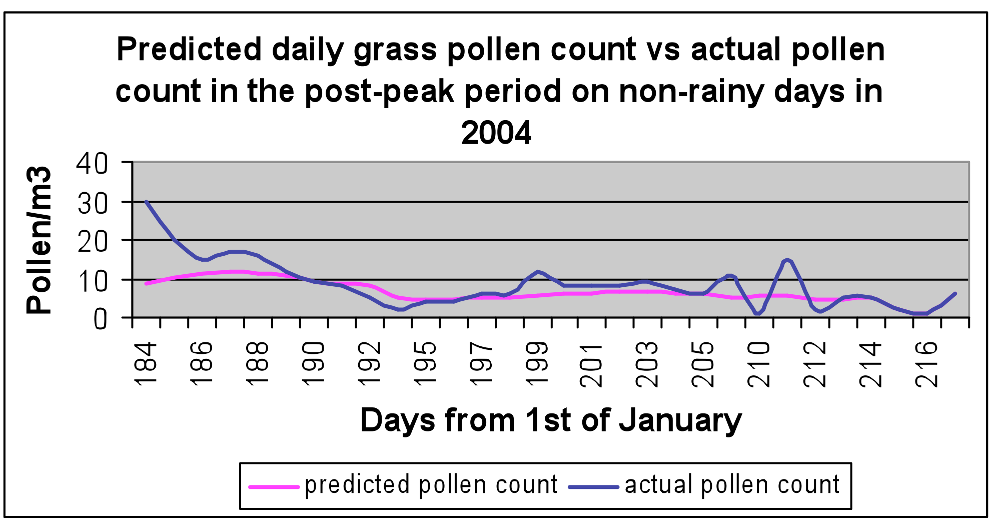


Fig. 23



6.14 APPRAISAL OF SHORT TERM FORECAST MODELS FOR GRASS INCLUDING THE MODELS ON NON-RAINY DAYS

The model developed to predict the daily grass pollen counts during the pre-peak period was based on variables such as temperature maximum and two- days running mean. The model was more robust when the variable two-days running mean was entered into the model.

The accuracy achieved was 69% in 2003 and 29% in 2004.

The model was able to predict the curve of the grass pollen during the pre-peak period.

The model developed for the prediction of daily grass pollen during the peak period was based on the variables temperature minimum and five days mean of normalised pollen counts. The prediction accuracy was 90% in 2003 and 68% in 2004.

Also the model constructed for the daily grass pollen counts during the post-peak period was based on variables such as temperature minimum and two-days running mean .The model was able to achieve an accuracy of 65% in 2003 and 87% in 2004. It should be mentioned that the post-peak period is more related to biological rhythms of the plants rather the meteorological factors. Still the model was able to predict the trend of the grass pollen during the post peak period.

More pollen data will be able to make the models more robust and give a better understanding of the factors that influence the pollen behaviour during the pollination season.

The model constructed to predict the daily grass pollen count during the pre-peak period on the non-rainy days showed that the two days running mean of normalized grass pollen counts and temperature minimum were the best weather parameters to be used.

The percent accuracy obtained was 70% in 2004 and the model was tested only in 2004 due to the lack of rainfall during the pre-peak period of grass pollen in 2003. The curve of the grass pollen count was predicted with a slight deviance.

The model did have a good improvement of accuracy in 2004 with a 40% increase compared with the one when the rainy days were included.
The model used to predict the daily grass pollen count on the non-rainy days for the peak period was based on the two days running mean of daily grass pollen and temperature minimum as the weather parameters.
The accuracy obtained with this model was equal to 69% in 2004.The model has an increase of accuracy of 1% when was tested in 2004. The peak period in 2003 was lack of rainfall so it was not possible for the model to be tested in year 2003. As it has been explained for the pre-peak period the small number of days with rainfall could be the reason that this model was not very significant different from that one who used the rainy days.
The model used to predict the daily grass pollen count for the post-peak period on the non-rainy days was based only in two days running mean as the weather parameter. The percent accuracy achieved with this model was equal to 65% in 2003 and 87% in 2004. It has shown that the accuracy of the models was the same when the rainy and non-rainy days were included.
As a conclusion it can be stated that percent accuracy obtained with the model to predict the daily grass pollen count on the non-rainy days was increased with 40% in 2004 for the model on the pre-peak period, increase with 1% in 2004 for the model in the-peak period and the same accuracy for the post-peak period when compared with the one that did included the rainy days.

The weather parameters used for the model on the non-rainy days were not very different compared with those that did include the rainy days. The pollen concentrations of the previous days (two days running mean) seem to play an important role in predicting the grass pollen grain for the following days. Also the temperature minimum was the best predictor to be used across the running means values of pollen counts for the pre-peak and peak period while for the model that included the rainy days this variable was found useful only for the grass peak period.
The post peak period for the model that used the non-rainy days was influenced more by the grass pollen concentrations of the five days in advance while the same model that

included the rainy days was found to be influenced by the temperature minimum beside the pollen concentrations of the two days beforehand.

The model for the daily grass pollen count on the non-rainy days needs to be tested on more than two years.

CHAPTER SEVEN: SECTION ONE
FORECAST MODELS FOR MAIN CHARACTERISTICS OF OLEA POLLEN IN TIRANA

A wide range of meteorological variables were considered in correlation analysis in chapter five in order to determine which if the weather parameters give the best explanations of the main features of the Olea pollen season.

A number of variables were examined for the possible inclusion into the linear regression. The selection of such variables was chosen after consulting other studies made by different authors. In the forecasting of the start of the Olea pollen season the parameters used were daily average temperatures as monthly means, ten days means, twenty day means, the total monthly precipitation, ten days means, twenty days mean rainfall etc (Appendix C). The variables that gave the highest correlation were included in the model. As the sample size is very small it was decided to use the simple linear regression when constructing the models for the main characteristics of the pollen season. For the start of Olea pollen season it is was decided to use the method 1 which defines the start as the date on which 1 pollen/m^3 is recorded in the samples when the Burkard- type volumetric samples is used and when subsequent days (at least five consecutive days) also show 1 or more pollen grains/m3 [Garzia-Mozo *et al.,* 1999]. For the start of the Olea pollen season several variables have been used such as accumulated growing – degree days and accumulated daily mean temperatures, thermal sum, number of days below 5^oC in January and February. The end of the pollen season is considered the last day when 1 pollen grain/m^3 has been recorded with the volumetric method following by days(at least three consecutive days) with no pollen grain present in the air. The length of the Olea pollen season is considered as equal to the number of days between the start and end date of Olea pollen season while severity is characterized by the total yearly Olea pollen count. The start of the peak count is the date when the highest pollen count has been recorded and the end of the peak is considered equivalent 80% of the accumulated percent values. The start of peak period was considered using the Pathirane method

[Pathirane, 1975] and detail explanations for this has been given in chapter six in the introduction of the chapter.

7.1 START OF THE OLEA POLLEN SEASON

The Olea pollen season in Tirana for the four years of study usually started in the middle of May. The Olea pollen season in Tirana is characterized by a period of short intense pollen counts with the presence of pollens for no more than 45 days. The range in differences between start of the season during the study years is 16 days. The earliest start day was registered in 2002 (day 129) and the latest start was registered in 1996 (day 145). The spring of 1996 was characterized by the lowest temperature maximum means in February and March respectively 12°C and 13°C, compared with the other study years which explain the latest start of the Olea pollen season observed in this year and this coincides with the latest day start for the grass pollen season too. It seems that temperature maximum does have a notable influence on the main characteristics of the pollen season significatively for both Olea and Grass. In 2002, the temperature mean in February and March was higher compared with the other years which explains the earlier start of the Olea pollen season in this year (respectively 16^{o} C and 18 ^{o}C in February and March- Appendix U**)**.

A model was developed using the Pearson correlation to determine which environmental variables have the most significant impact on the Olea pollen count. Then this model was used in an attempt to predict the start of the pollen season using the simple linear regression model. It should be mentioned that 30 day aggregated variables gave the highest level of explanation in this case the temperature maximum on days 51-70. These results showed clearly the relationship between the start of the Olea pollen season and the maximum temperature recorded during the months before the flowering period. This has been shown by different authors such as Alba *et al.,* 1998, Frenguelli *et al.,* 1989; Fornaciari *et al.,* 1998]. The mean temperature maximum between the days 51-70 starting from the 1st of January, which correspond to the period of 19/2-11/3 was among thirteen chosen variables which gave the best explanation of the start of Olea pollen season with the meteorological variables. The correlation coefficient was -0.999** and correlation was significant at the 0.01 level (2-tailed). The negative correlations achieved indicate that the higher the temperature mean gets the earlier the start of the pollen season start. Then the variable Tmax mean 51-70 was entered into the simple linear regression in order to predict the start of the Olea pollen season in Tirana.

The simple linear model which predicted the start date of the Olea pollen season achieved 99.7 % explanation, having the Adjusted R Square= 0.996 (Appendix L1: under the table Model Summary)
The simple linear regression is shown below.

Start day of Olea pollen= 166.376 - (1.960 x T Max mean on days 51-70)

Table 24 Accuracy of the model predicting the start date of the Olea pollen season

Year	Predicted start of the Olea pollen season (number of days from 1st of January)	Actual start of the Olea pollen season (number of days from the 1st of January)
2003	135	134
2004	141	121

The predicted model enabled the start of the Olea pollen season to be forecast in 2003 with 99% accuracy and 85.8% in the year 2004 (Table 24).
Also the predicted model can to be applied easily in Tirana as the meteorological variable required (Tmax mean 51-70 from the first of January) could be used easily before the Olea pollen season start date. The result achieved from the model to predict the grass pollen season, agreed with the same work of different authors that the temperature close to the start of the pollen season appeared to be an important variable in constructing models for the start of the Olea pollen season [Frenguelli *et al.,* 1989].

7.1.1 START OF THE OLEA POLLEN SEASON USING VARIOUS METHODS

Several other variables were taken into consideration to predict the start of the Olea pollen season. The variables used in the present study were:

1. Number of days when mean temperature was below threshold temperature (5^oC) in January and February,

2. Accumulated growing degree days from 1st of March to the beginning of pollens in the air

3. Thermal sum (sum of daily temperature over 5^oC for two different periods (15Feb-15March, 15 March- 15April),

4. Accumulated temperature maximum from the 1st of January till the starting point.

1. **Number of days when mean temperature was below threshold temperature 5^oC in January and February.**

   This variable was used as an attempt to predict the start of Olea pollen following the methods used by other authors [Frenguelli *et al.,* 1989, Alcala and Barrando, 1992]. It has been used in order to analyze the meteorological conditional effect before the flowering phase. When this variable was entered into the correlation analysis it did not make any contribution as a possible variable to forecast the start of Olea pollen season

2. **Growing degree- days (GDD) from 1st of January using 5□C as a threshold temperature**

   Heat units were calculated by obtaining the mean temperature each day subtracting a base temperature of 5^oC [Dennis., 1984] and accumulating the remainders (degree-days) for each day from 1st of March to the start of pollen concentrations of Olea. This variable has been used by many authors as Frenguelli *et al.,* 1989. This variable has been used as the flowering of Olea start is linked with a certain amount of accumulated heat. Therefore Olea is supposed to start to pollinate after obtaining a certain number of Growing Degree Hours (GDD). There are different approaches to how to find the best time for the accumulation of GDD. Many authors have used a fixed date for starting the accumulation (1st of January) and other has been used more complex models with the start after a dormancy period [Frenguelli *et al.,* 1992]. In this case were first calculated heat units by obtaining the mean temperature for each day subtracting the threshold temperature of 5^{o}C and accumulating those values already obtained from the 1st of March till the start of the Olea pollen season for each year. It attempts to predict the start of the Olea pollen season using a mean of accumulated growing-degree days during the four years of our study. The results are displayed in the table below (Table. 25).

Table 25 Accumulated growing degree days from the 1st of March till the start of Olea pollen season

Year	**Days from 1st of January**	**Accumulated GDD- with 5^{o}C threshold**
1995	136	584
1996	142	630
1998	135	514
2002	130	752
Mean (1995-2002)	136	**620**
2003- predicted year 2004- predicted year	131 121	628 537

This variable was able to predict the start of the Olea pollen season in 2003 in a very satisfactory way with 97% of accuracy while in 2004 the accuracy was equal of 86.6%.

3. Thermal sum (sum of daily temperature over 5°C for two different periods (15Feb- 15March, 15 March- 15April)

In order to give a better understanding of the decisive role of temperature in the start of the Olea pollen season, the variable ”thermal sum” has been used as this has been employed successfully by many authors [Fornaciari *et al.,* 1998]. The thermal sum was defined as the sum of daily temperatures over 5°C for two different periods (1. 15 Feb- 15 March, 2. 15 March- 15 April). When this variable has been entered into the correlation analysis it did not take any contribution to the start of Olea pollen season.

4. Accumulated temperature maximum from the 1st of January until the starting point.

Several cumulative methods have been used by different authors in order to predict the start of the Olea pollen season [Frenguelli *et al.,* 1989, Galan *et al.,* 2001 b]. The variable of accumulated maximum temperature from 1st of January until the start day of the Olea pollen season has been used in the present work. The table 26 displays the results obtained by using this variable.

Table.26 Accumulated maximum temperature 1st of January till the start date of the Olea pollen season

Year	**Days from 1st of January**	**Accumulated maximum temperature**
1995	136	2040
1996	142	2232
1998	135	2186
2002	130	2206
Mean (1995-2002)	136	**2166**
2003- predicted year 2004- predicted year	131 121	2203 1790

The variable accumulated maximum temperature from 1st of January till the start date of Olea pollen season was able to predict successfully the start of the Olea pollen season with a delay of one day. The accuracy achieved for the year 2003 was 98% while for year 2004 was 81.5%.

7.2 THE END OF THE OLEA POLLEN SEASON

The same basic meteorological variables were used to forecast the end of Olea pollen season. The method used has been described earlier in this chapter.
The earliest end of the Olea pollen season with the method 1 was the year 2002 (day 158) and the latest end of the Olea pollen season was the year 1995 (day 185). As it could be expected by the start date of the pollen season, the earliest start should be followed by a earlier end and the same logic would follow the latest start. This is explained only for the earlier end date of the the Olea pollen season (year 2002), but not for the latest one. In the year 1995, the mean of temperature maximum in April was lower (21.7^{o}C) compared with the other years explaining the latest start of Olea pollen season for this year. The maximum difference in the end date of the pollen season between the years 1995 to 2002 was 27 days. Using the Pearson correlation, the mean temperature maximum during April gave the best explanation reaching a coefficient correlation of 0.998* (correlation was found to be significant at the 0.01 level (2-tailed). A negative correlation gives some explanation about why the higher temperatures maximum influences the onset of the end of the Olea pollen season. The variable" Tmax mean on days 91-120" was the best to be used in forecasting the end of the Olea pollen season through a linear regression model. Following this, a R square= 0.997* was achieved with Adjusted R Square= 0.995 (Appendix L2– Model summary).

The simple linear regression is shown below.

End day of the Olea pollen season= 366.201- (10.823 x Tmax mean on days 91-120)

Table 27 Accuracy of the model predicting the end date of the Olea pollen season

Year	Predicted end of the Olea pollen season (number of days from 1st of January)	Actual end of the Olea pollen season (number of days from the 1st of January)
2003	160	156
2004	140	179

The predicted model enabled the end date of the Olea pollen season to be forecast with 97.5 % accuracy while in 2004 with 39% accuracy (Table 27). The difference between the predicted end date of the Olea pollen season and the actual date was with the range of 4 days difference in year 2003 and 39 days for year 2004.

7.3 SEVERITY OF THE OLEA POLLEN SEASON

In order to forecast the severity of the Olea pollen season, the same basic combination of the meteorological parameters was used as for the start and the end of the Olea pollen season. Using the framework of the correlation analysis the variable "Tmin" (temperature minimum) gave the best explanation achieving a correlation coefficient of 0.997 with a correlation significant at the 0.05 level (2-tailed). From the results displayed, it seems that the temperature minimum on days 51-90 (19/2-31/3) does influence the severity of the Olea pollen season. A lot of researchers have emphasized the importance of the" Alternance Production" factor, observed with olive trees [Macchia *et al.,* 1991]. This important factor leads to the alternating high and low levels of pollen from year to year. In Tirana the pattern of alternate high and low years is not distributed but there is some evidence of slight pattern. The variable Tmin on days 51-90 was entered into the simple linear regression, in order to obtain a model to forecast the severity of the Olea pollen season.

The simple linear regression used to predict the severity of the Olea pollen season achieved 99.3 % of explanation, having the Adjusted R Square = 0.990 (appendix L3: Model Summary)

The simple linear regression is shown below.

Severity of the Olea pollen season= 389.569 + (220.125 x Tmin mean on days 51-90)

Table 28 Accuracy of the model predicting the severity of the Olea pollen season

Year	Predicted severity of the Olea pollen season	Actual severity of the Olea pollen season
2003	1093	1294
2004	2062	1249

The model enabled the severity of the Olea pollen season to be forecast with 84% accuracy in 2003 and 60.5% in 2004 (table 28).

7.4 LENGTH OF THE OLEA POLLEN SEASON

In order to forecast the length of the Olea pollen season the same basic meteorological variables were used as for the start, end and severity of the Olea pollen season.

All these meteorological parameters were used in the correlation analysis and the variables with the highest coefficient correlation were used in the simple linear regression. Various periods of time for the aggregation of the variables were investigated (for example more than ten days) in order to determine the most suitable variables to use (Appendix C). It was found that the temperature minimum on days 51-90 (19/2-31/3)

gave the best explanations with the length of the Olea pollen season which was the same variable used to predict the severity of the Olea pollen season. The temperature minimum during the last ten days of February and during March showed a positive correlation with the length of the Olea pollen season. The higher the mean of the temperature minimum in this period, the longer the length of the Olea pollen. The correlation coefficient achieved using the Pearson correlation was 0.977 with the significance of correlation at the 0.05 level (2-tailed). Using the simple linear regression the variable" T min mean on days 51-90" achieved the highest Adjusted R Square= 0.933 (Appendix L4 : Model Summary)
The simple linear regression used to predict the start date of the Olea pollen season achieved 93.3 % explanation.
The simple linear regression is shown below.

Length of the Olea pollen season= 21.237+ (3.554 x T min mean on days 51-90)

Table 29 Accuracy of the model predicting the length of the Olea pollen season

Year	Predicted length of the Olea pollen season (number of days from 1st of January)	Actual length of the Olea pollen season (number of days from the 1st of January)
2003	32	22
2004	48	58

The model enabled the length of the Olea pollen season to be forecast with 69 % accuracy in 2003 and 83% accuracy in 2004 (Table 29). The difference between the forecast and actual length of Olea pollen season was 10 days in both years, 2003 and 2004.

7.5 START DAY OF PEAK COUNT FOR OLEA POLLEN SEASON

To forecast the day of peak count for the Olea pollen season the same combination of the meteorological variables were used as for the other features of the main grass pollen season (Appendix C1).

It was observed that the peak count had a tendency to start earlier as the data in our study has shown and probably this is linked to differences in weather between years. The peak count in 1995 was registered on day 153, in 1996 on day 149, in year 1998 on day 143 and in year 2003 on day 139.

All these meteorological parameters were used in the correlation analysis and the variables with the highest coefficient correlation were used in the simple linear regression. It seems that the rainfall mean in the first twenty days of March does influence the start day of peak count of the Olea pollen season. The correlation analysis showed a positive correlation with this meteorological variable explaining that the more rainfall that is experienced in this period (days from 61-80 starting from the 1st of January) the later the start of the peak count for Olea with be observed. The correlation coefficient achieved was 0.997 with the signification at the 0.01 level (2-tailed).

Using the simple linear regression the variable ”rain mean on days 61-80” achieved the highest Adjusted R Square=0 .991 (Appendix L5 : Model Summary).

The simple linear regression predicting the start date of peak count for Olea achieved 99.4 % explanation.

The simple linear regression is shown below.

Start of the peak period for Olea pollen = 137.654 + (1.686 x rain mean on days 61-80)

Table 30 Accuracy of the model predicting the start day of the peak count for Olea pollen

Year	Predicted the start day of the peak count for Olea (number of days from 1st of January)	Actual the start day of the peak count for Olea (number of days from the 1st of January)
2003	139	141
2004	146	151

The model enabled the start of the peak count for Olea pollen season to be forecast with 99 % accuracy in 2003 and 96.6% accuracy in 2004 (Table 30). The difference between the predicted and actual date of start of peak period for Olea was 2 days in year 2003 and 5 days in year 2004.

7.6 APPRAISAL OF LONG TERM FORECAST MODELS FOR OLEA

The long term models developed for the start of Olea pollen season were based on more than one method. The variable Temperature maximum on days 51-70 (mid February till mid March) was able to forecast the start of Olea pollen season with an accuracy of 99.2% in 2003 and 85.8% in 2004. The difference between the forecast and actual start date of Olea pollen season was 1 day when the model was tested in 2003 and 20 days when the model was tested in 2004. This variable reveal the same findings from other researchers that the variable that affect the start of Olea pollen season is the mean temperature in February and March [Frenguelli *et al.,* 1989; Alba& De la Guardia *et al.,* 1998; Moriondo *et al.,* 2001] although Olea has a late start of flowering compared with other temperate tree species. This shown a clear relationship between the temperatures during the development of buds produced during the preceding year.

Temperature is one of the main factors that affect the flowering of the Mediterranean trees [Galan *et al.,* 2001 a]. In the case of Olea europeae L., a low temperature period prior to bud development is essential to interrupt dormacy and after this, the plant accumulated heat until flowering starts. This is the reason why the start of Olea pollen season was predicted with other phonological methods like heat units expressed as growing degree- days. It was found the average accumulated number of heat units to induce flowering of Olea was 620^{o}C. When this threshold was tested in year 2003 it achieved an accuracy of 97% in 2003 (with 628^{o}C and 86% in 2004 (with 537^{o}C). Other studies have revealed an average of accumulated number of heat units from 180^{o}C in Malaga to 422^{o} in Granada [Galan *et al.,* 2004].

The different threshold achieved for the number of heat units reveal the relationship of this threshold temperature to the biogeographically characteristics. A higher altitude reveals an lower threshold temperature.

It should be mentioned Tmax for January in 2004 was 4^{o}C lower than in the previous year and higher with 2.8^{o}C in February. The year 2004 was not very usual year compared with others as well for the Tmax and min recorded in April-June with 2-6^{o} C more then the same period in the previous year.

Also the same observation was obtained with the variable accumulated temperature from the 1st of March. The threshold accumulated temperature predicted from the mean of four years of the study was 2166°. This threshold when tested in 2003 was reached at 2203°C and in 2004 at 1790°C. The threshold value reached for the year 2004 could be explained due to the specific meteorological conditions such as Temperature maximum and Temperature minimum.

The Olea pollen season in 2004 started ten days earlier (day-121) than in year 2003 (day-131).

The models used to predict the end of Olea pollen season was based on the variable Temperature maximum mean on days 91-120, that means during the month of April. It has been emphasized by many authors that the meteorological factors during the pollen production may influence to the end date of Olea pollen season [Keynan *et al.,* 1989; Frenguelli *et al.,* 1989]. When the model was tested in year 2003 the accuracy was achieved was equal of 97.5% with an difference of four days from the predicted date of the end of Olea pollen season. In the year 2004, the accuracy obtained for the prediction of end of Olea pollen season was 78.2% with an difference of 39 days. The model did not worked well in the year 2004.

The model to predict the severity of Olea pollen season was based on variable Temperature minimum on days 51-90, the temperature minimum during March. When the model was tested in year 2003, it achieved an accuracy of 84.4% in year 2003 with an difference of 201 p/m3 in year 2003 and an accuracy of 60% in year 2004 with an difference of 813 p/m3 in year 2004. Again the temperature plays an crucial role to the determination of the severity of Olea pollen season. As with the model for the end of the pollen season, it worked better for the year 2003 compared with year 2004. The biennal pattern of pollen production reported by some studies for tree species [Galan *et al.,* 1998; Emberlin *et al.,* 1990] has been not observed in the current study. Again more data set will influence to observe closely this phenomenon.

The model to forecast the length of Olea pollen season was based on variable Temperature minimum on days 51-90, the same variable that was used to predict the severity of Olea pollen season. The model worked quite well for both tested years with an accuracy of 68.7% in year 2003 and accuracy of 82.7% in year 2004. There was an difference of 10 days between the predicted and observed value for both years 2003 and 2004. The temperature minimum during Mid February till the end of March does influence the length of Olea pollen season. The temperature minimum for February in 2004 was 3.5^{o}C lower then the same variable in 2004 while in March was 2.8^{o}C lower than in 2004. This explains the difference on the length of Olea pollen season between year 2003 and 2004.

The different range of Olea pollen counts over the study years indicate even not very distinct pattern that as the Olea pollen season lengthened, the number of days with concentrations of less than 80p/m^3 increased and on contrary, when the Olea pollen season shortened, the number of days with concentrations more than 80p/m^3 increased considerably, this presenting a short but intense Olea pollen season. This has been mentioned in the study of [Diaz de la Guardia *et al*., 2003] even the Olea pollen concentrations in Spain exceed the daily values of 100p/m^3.

The model for the start day of peak count was built on the variable rain mean on days 61-80. The model for start of peak count also worked very well with a difference of 2 days in year 2003 and 5 days in year 2004. The accuracy achieved was equal with 98 % in year 2003 and 96.6 % in year 2004.

The models developed for the main characteristics of Olea pollen season were more robust when tested in year 2003 than in year 2004. The specific meteorological conditions of the year 2004 in Tirana might have influenced to this difference.

CHAPTER SEVEN : SECTION TWO
DEVELOPING DAILY FORECAST MODELS FOR OLEA POLLEN IN TIRANA

The daily forecast model for Olea pollen in Tirana was constructed for two different periods of the Olea pollen season, pre-peak and post-peak. The pre-peak period is considered to be the period from the start of the Olea pollen season with method 1 until the highest Olea pollen count and the post-peak period was considered to be the period from the day after the highest pollen count till the end of Olea pollen season with method 1 (Chapter 4.4). Some attempts were made initially to divide the Olea pollen season into three periods namely pre-peak, peak and post peak, but in the present research work the sample size is small and as the Olea pollen season is very short so it was not possible to use the peak period as a separate one from the post-peak period.

Two regression models were constructed as follows:

1. Multiple regression model in order to forecast the daily variations of Olea pollen counts during the pre-peak period
2. Multiple regression model in order to forecast the daily variations of the Olea pollen counts during the post-peak period

The same meteorological variables as used in the daily grass pollen forecast were used in the daily Olea pollen forecast. All the environmental variables (temperature maximum, temperature minimum, rainfall, five days running mean of pollen counts, four days running mean of pollen counts, three days running mean of pollen counts and two days running mean of pollen counts) were subject to correlation analysis in order to choose the variables with the higher correlation coefficient for entering into the multiple regression. As it has been explained in chapter six, further attempts were made to use the wind direction and wind data in the model (Appendix X5-X8). Before doing this, the Kruskal Wallace test was performed to check if these variables did make any contributions to the variations daily Olea pollen counts. This procedure has been explained in detail in chapter six. The wind variables did not have any significant relationships with the daily Olea pollen counts so they were discarded from the data set.

The multiple regressions were calculated using the relationships between the daily Olea pollen counts and the meteorological data with the highest correlation coefficient for each period in order to construct models for daily Olea pollen. A conversion of all the forecast models obtained from the equation was made to the normal working scale (p/m^3). Predicted values were squared and tested with the actual daily Olea pollen counts from the 2003 and 2004 season.

It was decided to use the threshold levels for Olea pollen as used in Italy (Spring project-table. 31).

Table 31

Olea pollen counts (p/m3)	Threshold used	Numerical score
1-4	low	1
5-24	moderate	2
25-200	high	3
≥ 200	very high	4

Predicted Olea pollen counts obtained by correlation analysis were compared with the real (observed) data in order to check if the models were strong enough to predict the patterns of the Olea pollen counts. The correlation analysis showed that the forecast daily model for Olea in the pre-peak period was sufficiently robust to explain the pattern of daily Olea pollen counts.

It should be mentioned that the Olea pollen season in 2003 was short with length of only 22 days. This year used for testing should be regarded with some caution.

The temperature mean for 2003 in February was the lowest compared of the study years. The value for this month was registered as 10C. Also the temperature mean for May and June was the highest in the data set, respectively 28°C and 32°C. This could explain the short length of the Olea pollen season in 2003 which it seems was an unusual year when it comes to the pattern of the pollen season. March 2003 was characterized by a lack of rainfall. This was only 6mm and was the lowest rainfall month compared with the other years. Also in 2003 April and May have the lowest rainfall amounts compared with the same months during the other years.

7.7 DAILY MULTIPLE REGRESSION MODEL FOR THE PRE-PEAK PERIOD OF THE OLEA POLLEN SEASON IN TIRANA

The meteorological variables used to forecast the daily Olea pollen count during the pre-peak period were 5-days running mean of normalized pollen counts (0.557**) and temperature maximum (0.428**) with a correlation signification at the 0.01 level (2-tailed). These two meteorological variables were obtained through using the Pearson correlation (appendix M2). These two variables were used to construct a model for the daily Olea pollen season during the pre-peak period.
Before constructing the model a checking system for assumptions was performed.

7.7.1. Multicollinearity

The correlations between the variables in the model were provided in the table labeled Correlations (Appendix M1**).** The relationship between the independent variable (temperature maximum and five-days running mean of normalized pollen count) and the dependent variable (normalized Olea pollen) shows a clear relationship. The correlation between two independent variables was checked to see if it was high. In this case the correlation was 0.428 between normalized Olea pollen counts and temperature maximum and 0.389 between normalized Olea pollen counts and five days running mean of normalized pollen count. In this case the two variables have a bivariate correlation less than 0.7 [Tabanich *et al.,* 2001].
The column headed "Tolerance" was checked in case a very low value is detected as this presumes the possibility of multicollinearity. In this case the value was 0.796 therefore this value did not appear to have violated the assumption (Appendix M1).
The value under the column Tolerance is 0.796, which is not low so the model has not violated the assumption.

7.7.2 Outliers, Normality, Linearity, Homoscedascity, Independence of Residuals

Through the observation of the Normal Probability Plot there are no major deviations from normality. Therefore the point does not seem to lay straight diagonal line from bottom left to top right. In the Scatterplot box, most of the scores are concentrated in the center. All the extreme values at the Malanobis distance are above the critical value of 13.82 (Appendix M3).

7.7.3 Evaluating the model

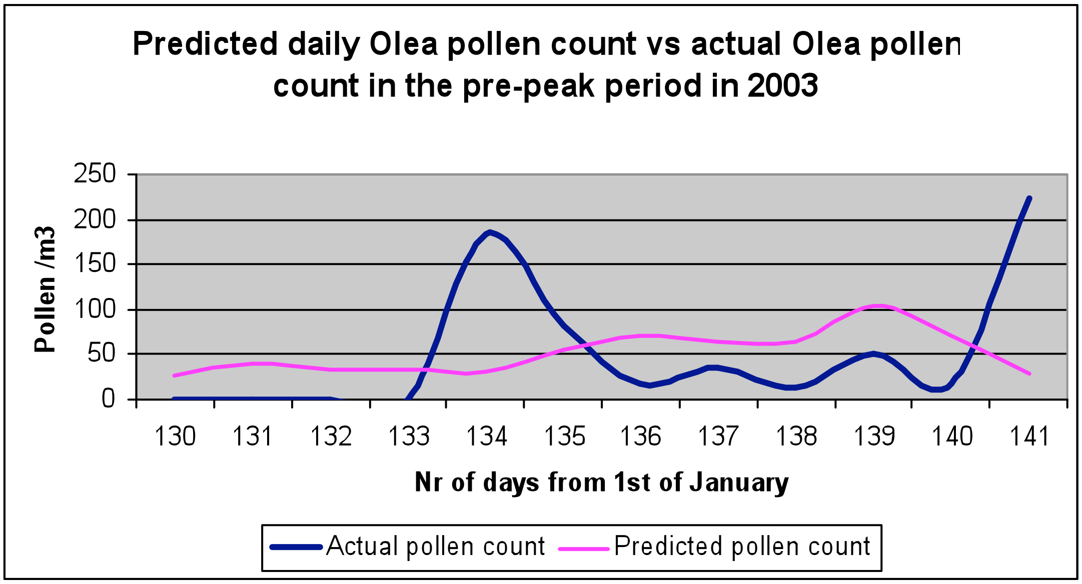
The R square under the Model summary box (Appendix M1) has a value of 0.349 therefore the model for the daily grass pollen count during the peak period achieved approximately 34.9 % of explanation. The adjusted R Square has a value of 0.32. Under the table Coefficients the Beta value are larger for five- day running mean of normalized pollen count than the temperature maximum.

The sample size for the peak period does not fulfill the requirement from Tabanich *et al.,* 2001 as it has only 48 cases.

Predicted daily Olea pollen = 5.519- (0.079 x Five-day + 0.366x Tmax)

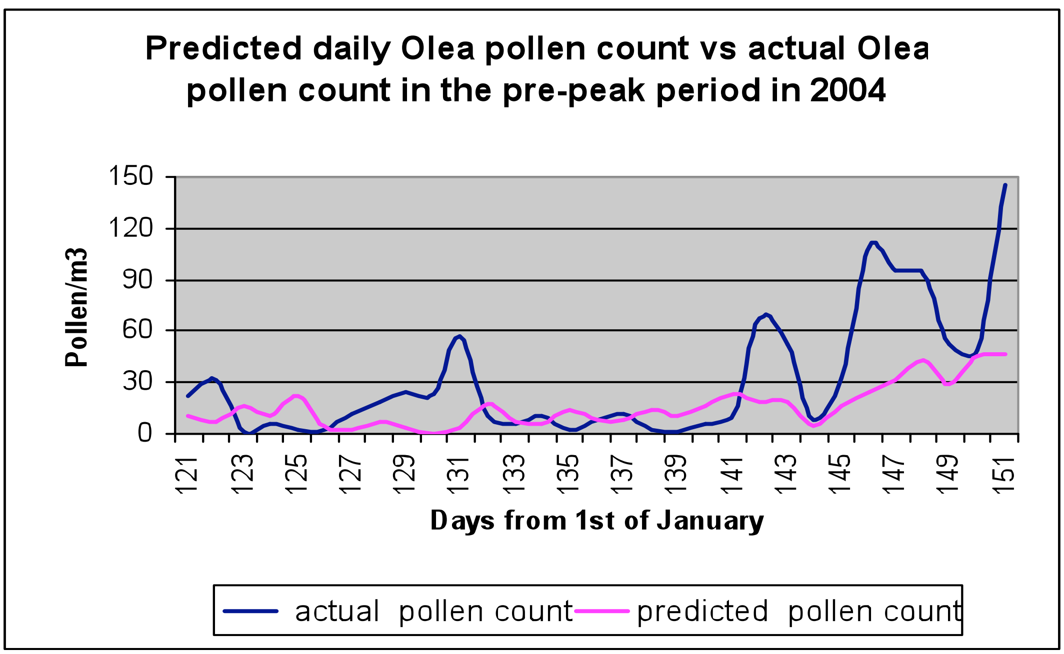
The predicted and actual daily Olea pollen counts were converted into numerical scores. Percent accuracy obtained was 42% in year 2003 and 57% in year 2004. Then the predicted and actual Olea pollen count were subjected to correlation analysis to check if the constructed model was able to predict the pattern of daily Olea pollen counts during the pre-peak period. The constructed model was able to predict the pattern of daily Olea pollen counts during the pre-peak period

Through using the Excel program the actual and predicted Olea pollen counts were compared (Fig. 24; Fig 25).



Predicted daily Olea pollen count vs actual Olea pollen count in the pre-peak period in 2003
Pollen /m3
250
200
150
100
50
0
130
131
132
133
134
135
136
137
138
139
140
141
Nr of days from 1st of January
Actual pollen count
Predicted pollen count

Fig.24



Predicted daily Olea pollen count vs actual Olea pollen count in the pre-peak period in 2004
Pollen/m3
150
120
90
60
30
0
121
123
125
127
129
131
133
135
137
139
141
143
145
147
149
151
Days from 1st of January
actual pollen count
predicted pollen count

Fig.25

7.8 DAILY MULTIPLE REGRESSION MODEL FOR THE POST-PEAK PERIOD OF THE OLEA POLLEN SEASON IN TIRANA

The meteorological variables used to forecast the daily Olea pollen count during the post-peak period were 4-days running mean of normalized pollen count (0.729**) and temperature maximum (-0.281**) with a correlation signification at the 0.01 level (2-tailed). These two meteorological variables were obtained through using the Pearson correlation (appendix M5). Before constructing the model a checking system for assumptions was performed.

7.8.1. Multicollinearity

The correlations between the variables in the model were provided in the table labeled Correlations (Appendix M1). The relationship between the independent variable (temperature maximum and four-days running mean of normalized pollen count) and the dependent variable (normalized Olea pollen) shows a clear relationship. The correlation between two independent variables was checked to see if it was high. In this case the correlation was 0.428 between normalized Olea pollen counts and temperature maximum and 0.389 between normalized Olea pollen counts and four days running mean of normalized pollen count.

The column headed "Tolerance" was checked in case a value very low is detected as this presumes the possibility of multicollinearity. In this case the value was 0.889 therefore this value did not appear to have violated the assumption (Appendix M4)

7.8.2 Outliers, Normality, Linearity, Homoscedascity, Independence of Residuals

Through the observation of the Normal Probability Plot there are no major deviations from normality. Therefore the point does not seem to lies straight diagonal line from bottom left to top right. In the Scatterplot box, most of the scores are concentrated in the center. The critical values at the Mahalanobis table are under the critical value of 13.8 (Appendix M6).

7.8.3 Evaluating the model

The R square under the Model summary box (Appendix M4) has a value of 0.533 therefore the model for the daily Olea pollen count during the post-peak period achieved approximately 53.3 % explanation. Adjusted R Square has a value of 0.523. Under the table Coefficients the Beta value are larger for four- day running mean of normalized pollen count than the temperature maximum.

The sample size for the post-peak period does not fulfill the requirement from Tabanich et al., 2001 as it has only 57 cases.

Predicted daily Olea pollen = 3.580+ (0.060 x Four-days - 0.059x Tmax)

The predicted and actual daily Olea pollen counts were converted into numerical scores. Percent accuracy obtained was 57% in year 2003 and 82% in year 2004. Then the predicted and actual Olea pollen count were subjected to correlation analysis to check if the constructed model was able to predict the pattern of daily Olea pollen counts during the post-peak period. The constructed model was able to predict the pattern of daily Olea pollen counts during the post-peak period.

Through using the Excel program the actual and predicted Olea pollen counts were compared (Fig. 26 and Fig. 27).

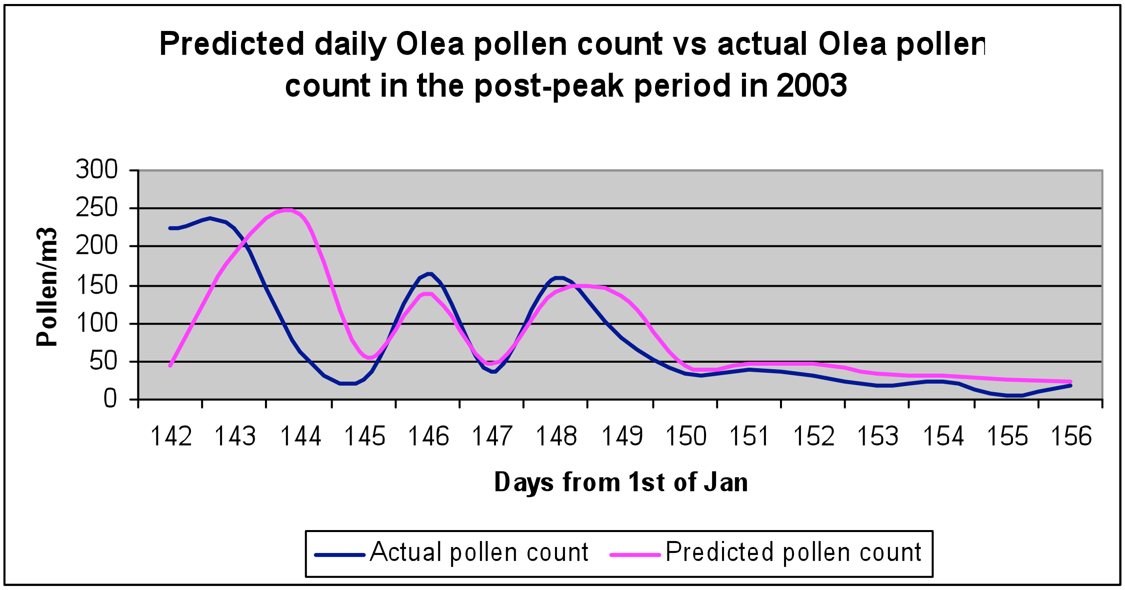

Predicted daily Olea pollen count vs actual Olea pollen count in the post-peak period in 2003
300
250
200
150
100
50
0
Pollen/m3
142 143 144 145 146 147 148 149 150 151 152 153 154 155 156
Days from 1st of Jan
Actual pollen count
Predicted pollen count

Fig.26

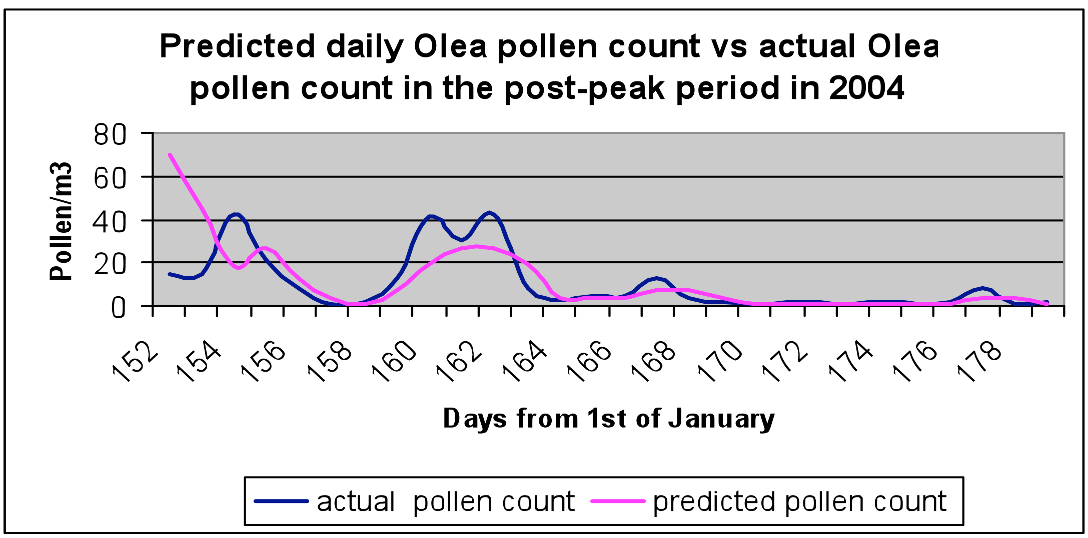

Predicted daily Olea pollen count vs actual Olea pollen count in the post-peak period in 2004
80
60
40
20
0
Pollen/m3
152 154 156 158 160 162 164 166 168 170 172 174 176 178
Days from 1st of January
actual pollen count
predicted pollen count

Fig.27

CHAPTER SEVEN: SECTION THREE
DEVELOPING DAILY FORECAST MODELS FOR OLEA POLLEN IN TIRANA ON NON-RAINY DAYS

The short term daily forecast models for Olea pollen in Tirana on the non-rainy days was constructed for two different periods of the Olea pollen season, pre-peak and post-peak. The methodology on how the Olea pollen season divided has been explained in details in Chapter 4.4. Also the justification on how the Olea pollen season has been divided on two periods has been explained.

Two regression models were constructed as follows:

1. Multiple regression model in order to forecast the daily variations of Olea pollen counts on the non-rainy days during pre-peak period
2. Multiple regression model in order to forecast the daily variations of the Olea pollen counts on the non-rainy days during the post-peak period

The same meteorological variables as in daily Olea pollen forecast that included the rainy days were used to predict the daily Olea pollen count on the non-rainy days. All the environmental variable (temperature maximum, temperature minimum, rainfall, five days running mean of normalized Olea pollen counts, four days running mean of normalized Olea pollen counts, three days running mean of normalized Olea pollen counts and two days running mean of normalized Olea pollen count) were subject to correlation analysis in order to choose the variables with the higher correlation coefficient for entering into the multiple regression.

The multiple regressions between the daily Olea pollen counts on the non-rainy days and the meteorological data with the highest correlation coefficient were carried out for each period in order to construct models for daily Olea pollen. A conversion of all the forecast models obtained from the equation was made to the normal work scale (p/m^3). Predicted values were squared and tested with the actual daily Olea pollen counts from the 2003 and 2004 seasons.

It was decided to use the threshold for Olea pollen as used in Italy (Table 32)

Olea pollen counts (p/m3)	Threshold used	Numerical score
1-4	low	1
5-24	moderate	2
25-200	high	3
≥ 200	extra high	4

Table.32

Predicted Olea pollen counts were compared with the real (observed) data obtained by correlation analysis in order to specify if the models were strong enough to predict the patterns of the Olea pollen counts.

It should be mentioned that the Olea pollen season in 2003 was exceptionally short with a length of only 22 days.
The temperature mean for 2003 in February was the lowest in the years considered. The value for this month was registered as 10□C. Also the temperature mean for May and June was the highest when compared with the same data set, respectively 28° C and 32°C. This could explain the short length of the Olea pollen season in 2003 which it seems was not a usual year when it comes to the pattern of the pollen season.
Also the total amount of rainfall was unusual for year 2003. March was characterized by lack of rainfall. A total of 6mm was recorded, the lowest rainfall for the month of March compared with the other years. Also the months of April and May have the lowest rainfall amounts in 2003 compared with the same months during the other years.
As regards to the Olea pollen season in year 2004, the pollen season was longer then in year 2003, almost double as the previous year. Although the Olea pollen season in 2004 started almost ten days earlier than in 2003. If the Temperature mean of February are compared still its value for 2004 id recorded as a value of 12.8° C, almost 2.8 C more than the year 2003. Rainfall has been quite abundant in 2004 with its total sum of 216mm in January, 119.5mm in February, 168.1mm in March and 140.8mm in May. There was

no rainfall during the pre-peak of Olea pollen season. The model developed was tested only in year 2004 due to the lack of rainfall in 2003**.**

7.9 DAILY MULTIPLE REGRESSION MODEL FOR THE PRE-PEAK PERIOD OF THE OLEA POLLEN SEASON ON THE NON-RAINY DAYS IN TIRANA

The meteorological variables used to forecast the daily Olea pollen count on the non-rainy days during the pre-peak period were 5-days running mean of normalized Olea pollen count (0.400**) and temperature minimum (0.361*) with a correlation signification at the 0.01 level (2-tailed). These two meteorological variables were obtained through using the Pearson correlation (appendix N.2). These two variables were used to construct a model for daily Olea pollen season during the pre-peak period on the non-rainy days.

Before constructing the model a checking system for assumptions was performed.

7.9.1 Multicollinearity

The correlations between the variables in the model were provided in the table labeled Correlations (Appendix N1). The relationship between the independent variable (temperature minimum and five-days running mean of normalized Olea pollen count) and the dependent variable (normalized Olea pollen) showed a clear relationship. The correlation between two independent variables and independent variable was checked to see if it was high. In this case the correlation was 0 .545 between temperature minimum and five days running mean of Olea pollen count.

The column headed “Tolerance” was checked in case a value very low is detected as this presumes the possibility of multicollinearity. In this case the value was 0.703 therefore this value did not appear to have violated the assumption (Appendix N3).

7.9.2 Outliers, Normality, Linearity, Homoscedascity, Independence of Residuals

The Normal Probability Plot indicated that there are no major deviations from normality. Therefore the points do not seem to lie in a straight diagonal line from bottom left to top right. In the Scatterplot box, most of the scores are concentrated in the center. The values at the Mahalanobis distance table are all under the critical value (AppendixN3).

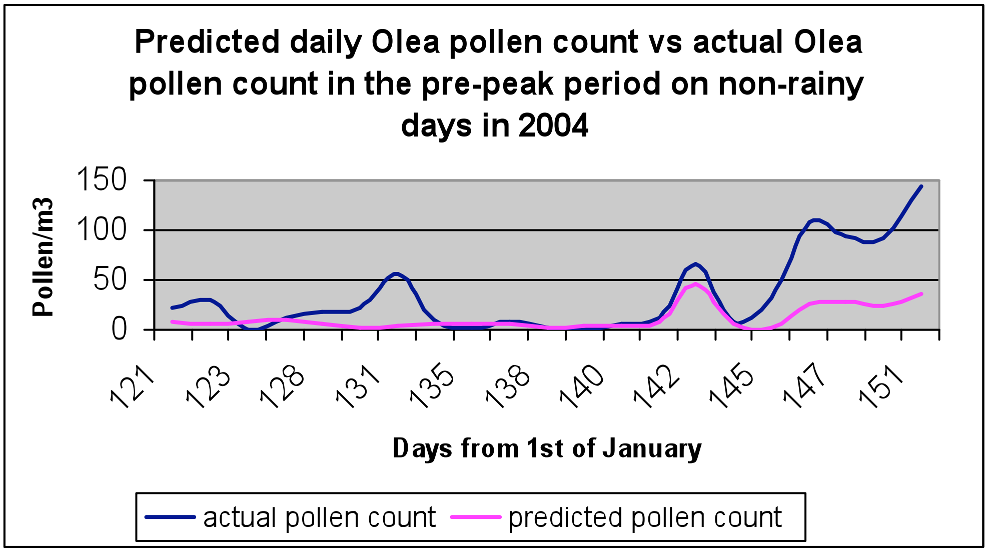
7.9.3 Evaluating the model

The R square under the Model summary box (Appendix N1) has a value of 0.189, therefore the model for the daily Olea pollen count during the pre-peak period achieved app 19% % of explanation. Adjusted R Square has a value of 0.151. The sample size for the peak period does not fulfill the requirement from Tabanich *et al.,* 2001 as it has only 48 cases.

Predicted daily Olea pollen on the non-rainy days = (0.039 x Five-day)+ (0.426x Tmin)-3.204

The pre-peak period for 2003 was characterized by lack of rainfall; therefore it was not possible to be used as a test year. The predicted and actual daily Olea pollen counts for 2004 were converted into numerical scores. Percent accuracy obtained was 60% in year 2004. Through using the Excel program the actual and predicted Olea pollen count were compared (Fig. 28).

Fig.28



7.10 MULTIPLE REGRESSION MODEL FOR THE POST- PEAK PERIOD OF THE OLEA POLLEN SEASON IN TIRANA ON THE NON-RAINY DAYS

The meteorological variables used to forecast the Olea daily pollen counts on the non-rainy days in the post-peak period were two and five days running mean of Olea normalized pollen counts. This relationship was found when the Pearson correlation was performed (Appendix N5). The same checking procedure was used as mentioned in 6.5 and 6.6.

7.10.1 Multicollinarity

Through the observation of the correlation between the independent variables no assumptions were detected.

The value under the column Tolerance is 0.192 therefore the model has not violated the assumption (Appendix N4).

7.10.2 Outliers, Normality, Linearity, Homoscedascity, Independence of Residuals

Through the observing of the Normal Probability Plot there are no major deviations from normality. In the Scatterplot box, most of the scores are concentrated in the center.

Outliers have been detected through the Mahalanobis distances produced by the multiple regression program. The critical chi- value for two independent variables is 13.82, the model has only one outlying cases (Appendix N6).

7.10.3 Evaluating the model

The R square under the Model summary box (Appendix N5) has a value of 0.376, therefore the model for the daily Olea pollen count during the post-peak period achieved app 37.6% of explanation. Adjusted R Square has a value of 0.344. Under the table Coefficients the Beta value are larger for two- day running mean than the five days running mean.

The sample size for the post-peak period fulfills the requirement from Tabanich *et al.,* 2001 with 118 cases.

Predicted daily Olea pollen on the non-rainy days = 5.332+ (0.038 x two-days)+ (0.021x five-days)

The predicted and actual daily Olea pollen counts were converted into numerical scores. Percent accuracy obtained was 65% in year 2003 and 36% in 2004 .Then the predicted and actual Olea pollen count were subjected to correlation analysis to check if the constructed model was able to predict the pattern of daily Olea pollen counts during the post-peak period. The correlation analysis has shown that the predicted pollen Olea during the post-peak period did predict the trend for Olea pollen in year 2003 but not in year 2004. Through using the Excel program the actual and predicted Olea pollen count were compared (Fig.29, 30).

Fig.29

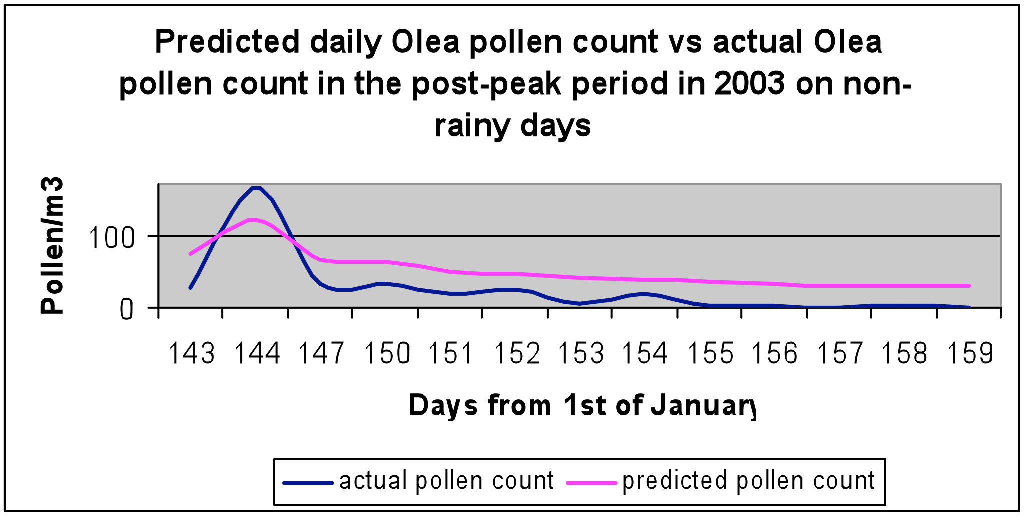
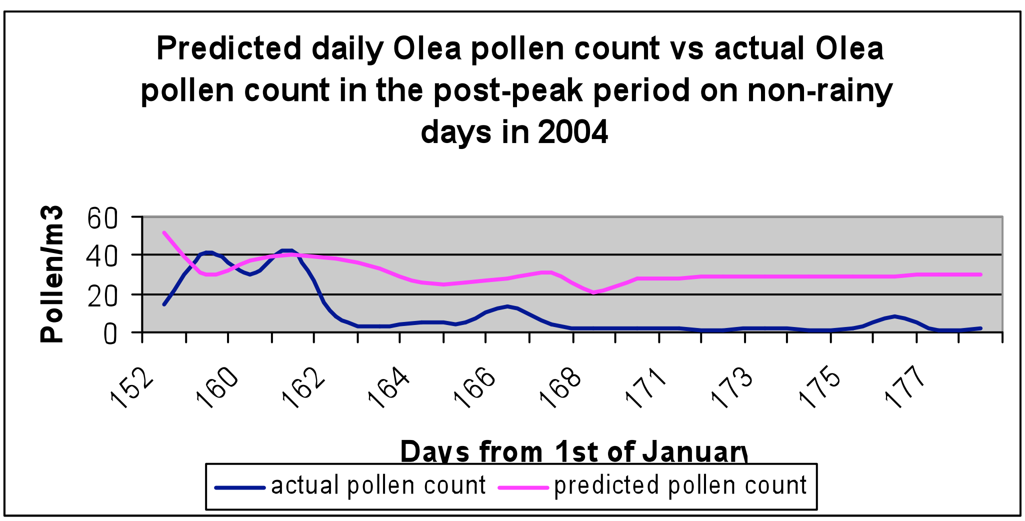

Predicted daily Olea pollen count vs actual Olea pollen count in the post-peak period in 2003 on non-rainy days
Pollen/m3
100
0
143 144 147 150 151 152 153 154 155 156 157 158 159
Days from 1st of January
actual pollen count
predicted pollen count

Fig.30


Predicted daily Olea pollen count vs actual Olea pollen count in the post-peak period on non-rainy days in 2004
Pollen/m3
60
40
20
0
152
160
162
164
166
168
171
173
175
177
Days from 1st of January
actual pollen count
predicted pollen count

7.11 APPRAISAL OF SHORT TERM FORECAST MODELS FOR OLEA INCLUDING THE MODELS ON NON-RAINY DAYS

The model constructed to forecast the daily Olea pollen counts for the pre-peak and post-peak period was based on the meteorological variables such as temperature maximum and running mean values (five-days running mean for pre-peak and four-days running mean for post-peak) of Olea pollen counts. Maximum temperatures have been shown by many researchers to be between the main heating factors affecting the daily Olea pollen variations [Dominguez *et al*., 1998; Recio *et al*., 1996; Galan *et al.,* 2001 a]. This variable has been mentioned that influence on the pollen emission by favoring dehydration and dehiscence of the anthers.

Also the use of the running mean values of Olea as a predictor to forecast the daily Olea pollen counts has been used by may authors like [Diaz de la Guardia *et al*., 2003; Galan *et al.,* 1998]. It has been proved that the pollen quantity recorded in one day is largely determined by the values registered on the preceding day. This has been shown in the significant correlation coefficients between Olea pollen counts and the running mean of the normalized Olea pollen count in the current research. Also the cumulative temperature values have been shown to correlate with the Olea pollen levels by many researchers [Recio *et al.,* 1996]. This variable when was enter to the correlation analysis did not show any significance. Yet, the larger data set will reflect the other factors both intrinsic and extrinsic on the dispersion of Olea pollen counts.

The biennal pattern of Olea pollen was not observed in the current study even this phenomen has been reported by some researchers [Galan *et al.,* 1998, Emberlin *et al.,* 1990].

The model constructed for the pre-peak (with the means of temperature maximum and five-days running mean) was able to predict the trend of daily Olea pollen count in 2003 but achieved good accuracy based in the reporting index system [Spring project] in year 2004. The curve of the Olea pollen season for year 2003 was different with the curve in year 2004 probably due to the specific conditions of the meteorological factors in year

2003. The Olea pollen season in year 2003 was shorter and the pre-peak was equal with 11 days while the pre-peak in year 2004 was equal of 30 days. The accuracy reached for the pre-peak in 2004 wad equal of 57% compared with 42% in year 2003. The pre-peak Olea pollen curve in 2003 was characterized by one peak which was recorded within the four days of the presence of Olea in the air, while the pre-peak Olea pollen curve in 2004 was more complex with three peaks, the highest one recorded at the end of the pre-peak period.

The model constructed to forecast the daily Olea pollen counts in the post-peak period was based on the combinations of temperature maximum and four days running mean of pollen counts. The post peak period was longer for year 2004 (26 days) then for the year 2003 (14 days). The model again worked better for the year 2004 achieving an accuracy of 52% than for the year 2003 with an accuracy of equal of 37%. As a conclusion the developed model to forecast the daily Olea pollen counts worked better in year 2004 than in year 2003 for both pre and post peak period.

According to Recio *et al.,* 1996, heat favours anther dehiscence during the Olea pre-peak period but makes flowering to decrease during the post-peak period since the heat is of the parameters that cause variations on Olea pollen counts. Since heat is related to the solar energy, other meteorological factors such as sunlight hours, accumulated sunlight hours should be considered as heating variable across the temperatures variables. Those factors need to be taken into consideration for future research. The rainfall and humidity have shown to be determinant into the daily Olea pollen variations [Dominguez *et al.,* 1993; Recio *et al.,* 1996]. When the variable rainfall was entered into the correlation analysis did not show any significance.

It should also noted that the pre-peak period is related to the biological phenomena such as pollen emission while the post-peak which coincide with the decreasing pollen concentrations in the air is related to the factors such as presence of pollen originating far from the sampling site, resuspension etc [Vazques *et al.*, 2003]. These factors are difficult to be predicted by the means of statistical analysis.

Daily Olea pollen variations as it has been shown by many studies is related to the heat-related variables such as temperature and hours of sunlight on pollen emission and dispersion [Dominguez *et al*., 1993; Recio *et al.,* 1996, 1997] while other parameters such as rainfall, wind speed and direction may affect the Olea pollen variations are depending on the geographical location [Recio *et al.,* 1996].

As the conclusion, daily Olea pollen variations in Tirana, is influence by the heat-related variables like temperature maximum and the pollen concentrations on the previous days (five and four –days).

The model constructed to predict the daily Olea pollen counts on the non-rainy days showed that the five days running mean and temperature minimum were the best weather parameters to be used during the pre-peak period. Due to the lack of rainfall in 2003, the developed model was tested only in year 2004. The Olea pollen season is a characterized by a short season, most of the time with only 50-60 days its presence in the air. The division of pollen season in two periods makes more difficult the construction of an objective forecast model to be built. The pre-peak period of Olea in year 2004 was recorded with only 10 days of rainfall.

Also during the Olea pre-peak period in 1995, 8 days were recorded with rainfall, in 1996 only one day, in 1998 three days were observed with rainfall and on 2002 there were six days.

The model used to predict the daily Olea pollen count on the non-rainy days for the post-peak peak period was based on the two days running mean and five days running mean. Compared with the one that included the rainy days this model, this was found to be high related to the Olea pollen concentrations of the previous days such as two and five days. The percent accuracy obtained with the model that used the non-rainy days was 38 % in 2003 and 36 % in 2004.

The post-peak period for the Olea in 2003 was also recorded with five days with rainfall. Also during the Olea post-peak period there were recorded four days of rainfall in 1996, two days of rainfall in 1998, and 10 days with rainfall in 2002.

The weather parameters used for the models on the non-rainy days were different. The temperature minimum and five-days running mean of Olea pollen counts were used as predictors for the model in the pre-peak period while the pollen concentrations of the

previous days (five days running mean and two days running mean) seems to play an important role to predict the Olea pollen counts for the post-peak period.
Again the temperature minimum has been shown to be considered among the heating factors that affect the daily variation of Olea [Galan *et al.,* 2001 a; Dominguez *et al*., 1993].

As the conclusion we can say that percent accuracy obtained with the model to predict the daily Olea pollen count on the non-rainy days was increased with 3% for the model on the pre-peak period and 1% for the model in the post-peak period.

CHAPTER EIGHT: SECTION ONE

FORECAST MODELS FOR THE MAIN CHARACTERISTICS OF THE URTICACEAE POLLEN SEASONS IN TIRANA

A wide range of meteorological variables were considered in correlation analysis in chapter five in order to determine which of the weather parameters give the best explanations of the main features of the Urticaceae pollen season.

A number of variables were examined for the possible inclusion in the linear regression. In the forecasting of the start of the Urticaceae pollen season the parameters used were daily average temperatures as monthly means, ten days means, twenty day means, the total monthly precipitation, ten days means, twenty days mean rainfall etc (Appendix D). The variables that gave the highest correlation were included in the model in the same way as for Grass and Olea.

For the start of the Urticaceae pollen season the 5% method has been used. Through this method the start of the pollen season of Urticaceae has been considered when 5% of cumulative values have been reached. The end of Urticaceae pollen season has been considered to be when 95% of the cumulative values have been reached. For the start and the end of peak period of the Urticaceae pollen season the same methodology as for grass has been used. The length of the Urticaceae pollen season is considered to be equal to the number of days between the start and end date of Urticaceae pollen season while severity is characterized by the total yearly Urticaceae pollen counts.

8.1 START OF THE URTICACEAE POLLEN SEASON

The Urticaceae pollen season in Tirana is characterized by a very long pollination period during which pollen is present in the air from April until November. The daily pollen count does not reach high values but pollen is persistent in the atmosphere for a long period due to the contribution of many species from the Urticaceae family. The pollination period of the members of the Urticaceae family overlap and therefore it is not possible to distinguish the pollen grains under the light microscope even though there are some slight differences in size of the pollen grains. The general term “Urticaceae” is often used which includes the genera of Urtica and Parietaria. The details about this family have been given in chapter 3.

The range in differences between start of the Urticaceae pollen season in different years is seven days with the earliest start being recorded in the year 1998 on 21/5 and the latest one in the year 1995 on 28/5.

A model was developed using the Pearson correlation to determine which environmental variables have the most significant important influence on the start of the Urticaceae pollen season (Appendix D). Then this model was used in an attempt to predict the start of the pollen season using the simple linear regression models. The reason for choosing the simple linear regression to predict the start of the pollen season has been explained in chapter five. It should be mentioned that 30 day aggregated variables gave the highest level of explanation, in this case particularly the temperature mean maximum on days 1-30 (January). These results show clearly the relationship between the start of the Urticaceae pollen season and the mean maximum temperatures recorded during January. The mean maximum temperature between the days 1-30, starting from the 1st of January, which corresponds to the period of 1-30/01, was among ten chosen variables which gave the best explanation of the start of the Urticaceae pollen season with the meteorological variables. The correlation coefficient was -0.997** with a significance at the 0.01 level (2-tailed)-Appendix O1).The negative correlations indicate that higher mean temperatures do lead to an earlier start of the pollen season. Then the variable” T mean 1-30”, was entered in the simple linear regression in order to predict the start of the Urticaceae pollen season in Tirana.

The simple linear model uses to predict the start date of the Urticaceae pollen season achieved 98 % explanation, and has the Adjusted R Square= 0.971 (appendix O1: under the table Model Summary)
The simple linear regression is shown below.

Start day of Urticaceae pollen= 163.750 - (2.5 x Tmax mean on days 1-30)

Table 33. Accuracy of the model predicting the start date of the Urticaceae pollen season

Year	Predicted start of the Urticaceae pollen season (number of days from 1^{st} of January)	Actual start of the Urticaceae pollen season (number of days from the 1^{st} of January)
2003	144	136
2004	137	98

The predicted model enabled the start of the Urticaceae pollen season to be forecast with 94 % accuracy in 2003 and 72% accuracy in 2004 (Table. 33).
The temperature mean in January for 2003 was $10^{o}C$ compared with an average of $8^{o}C$ temperature mean during the study years. In 2004 the temperature mean for January was $7.35^{o}C$. The temperature maximum mean in January in 2004 was $3.5^{o}C$ higher than in 2003, which resulted in an earlier start of Urticaceae pollen season in 2004 than in 2003.
The prediction model can be applied easily in Tirana as the meteorological variable required (Temperature mean on days 1-30 from the first of January) could be used before the Urticaceae pollen season starts.
The results achieved agreed with the work by Arobba *et al*., 1992, in which the authors were able to predict the start of main pollen season of Parietaria based on the meteorological data (temperature and rainfall) for the month of January.

8.2 THE END OF THE URTICACEAE POLLEN SEASON

The same basic meteorological variables were used to forecast the end of the Urticaceae pollen season (Appendix D). The method used has been described earlier in this chapter. The earliest end of the Urticaceae pollen season with the method 5% was in the year 1995 (day 271) and the latest end was in the year 2002 (day 301). As it could be expected by the start date of the pollen season, an earlier end should follow an earlier start and the same logic would follow a later start. This pattern is followed only for the latest date of the Urticaceae pollen season (year 2002) but not for the earlier one. In 2002, an amount of 32.4mm rainfall was registered during March while the total rainfall amount of 246 mm was recorded in the year 1995. The difference in the end date of the pollen season between years was 30 days. Using the Pearson correlation, the total amount of rainfall in March gave the best explanation for the end of the Urticaceae pollen season reaching a coefficient correlation of 0.998* (correlation was found to be significant at the 0.01 level, 2-tailed). A negative correlation result helps to explain why the absence of rainfall in March does influence the date for the latest end of the Urticaceae pollen season. The variable" Rain on days 91-120" was the best to be used in forecasting the end of the Urticaceae pollen season in a linear regression model. Following this, a R square= 0.998* was achieved with Adjusted R Square= 0.997 (Appendix O2– Model summary).

The simple linear regression is shown below.

End day of the Urticaceae pollen season= 305.828- (0.144 x Rain amount on days 91-120)

Table 34. Accuracy of the model predicting the end date of the Urticaceae pollen season

Year	Predicted end of the Urticaceae pollen season (number of days from 1st of January)	Actual end of the Urticaceae pollen season (number of days from the 1st of January)
2003	304	309
2004	304	248

The predicted model enabled the end date of the Urticaceae pollen season to be forecast with 99 % accuracy in year 2003 with only five days difference and an accuracy of 81% in 2004 with an difference of 56 days (table 34). In 2003, the total amount of rainfall during March was only 6.3mm the lowest compared with the other years, while in 2004 it was equal of 168.1mm.

8.3 SEVERITY OF THE URTICACEAE POLLEN SEASON

In order to forecast the severity of the Urticaceae pollen season the same basic combination of the meteorological parameters were used as for the start and the end of the Urticaceae pollen season. The severity of Urticaceae pollen season differs between the years, with the year 1995 having the highest total pollen sum of 1657 and year 1998 with a total pollen sum of 740 recorded with the volumetric trap. Using the framework of the Pearson correlation analysis, the variable “T max mean” (temperature maximum mean) on days 91-110, gave the best explanation achieving a correlation coefficient of 0.987 with a correlation significant at the 0.05 level (2-tailed). From the results displayed, it seems that the temperature maximum mean on days 90-110 (1-20/4) does influence the severity of the Urticaceae pollen season. The variable”T max mean on days 91-110” was entered in the simple linear regression in order to obtain a model to forecast the severity of the Urticaceae pollen season.

The simple linear regression predicting the severity of the Urticaceae pollen season achieved 98.7 % explanation, having an Adjusted R Square = 0.962 (Appendix O3: Model Summary)

The simple linear regression is shown below.

Severity of the Urticaceae pollen season= 8116.483 - (365.933 x Tmax mean on days 91-110)

Table 35. Accuracy of the model predicting the severity of the Urticaceae pollen season

Year	Predicted severity of the Urticaceae pollen season	Actual severity of the Urticaceae pollen season
2003	1181	1136
2004	980	2402

The prediction model enabled the severity of the Urticaceae pollen season to be forecast with 96% accuracy in 2003 and 41% accuracy in 2004 (Table 35).

8.4 LENGTH OF THE URTICACEAE POLLEN SEASON

The length of the Urticaceae pollen season varies between the study years. The range difference was 29 days. The longest Urticaceae pollen season was recorded in the year 1998 with 156 days, while the shortest Urticaceae pollen season occurred in the year 1995 with only 127 days. The total amount of rainfall during March in the year 1995 was 246.7 mm, the highest amount compared with the other years for the same period. In the years 1998 and 2002, the lack of heavy rainfall in March was linked with a longer Urticaceae pollen season.

In order to forecast the length of the Urticaceae pollen season, the same basic meteorological variables were used as for the start, end and severity of the Urticaceae pollen season.

All these meteorological parameters were used in the correlation analysis and the variables with the highest coefficient correlation were used in the simple linear regression. It was found that the total amount of rainfall on days 61-90 (1-30/03) gave the best explanations for the length of the Urticaceae pollen season, the same variable used to predict the end date of the Urticaceae pollen season. The total amount of rainfall in March showed a negative correlation with the length of the Urticaceae pollen season. The absence of rainfall during the mentioned period does exert an influence and results in a longer Urticaceae pollen season. The correlation coefficient achieved using the Pearson correlation was 0.989 with the significance of correlation at the 0.05 level (2-tailed). Using the simple linear regression the variable rain total on days 61-90 achieved the highest Adjusted R Square= 0.966 (Appendix O4 : Model Summary). The simple linear regression predicting the length of Urticaceae pollen season achieved a level of 97.7 % explanation.

The simple linear regression is shown below.

Length of the Urticaceae pollen season= 162.132- (0.144 x rain amount on days 61-90)

Table 36. Accuracy of the model predicting the length of the Urticaceae pollen season

Year	Predicted length of the Urticaceae pollen season (number of days from 1st of January)	Actual length of the Urticaceae pollen season (number of days from the 1st of January)
2003	161	135
2004	138	151

The predicted model enabled the length of the Urticaceae pollen season to be forecast with 84 % accuracy in 2003 and 93% in 2004 (Table 36).

8.5 THE START DATE OF THE PEAK PERIOD FOR URTICACEAE

The start of the peak period for Urticaceae was chosen according to Pathirane, 1975. This method has been explained in detail in chapter four.

According to Pathirane, 1975, the peak period for Urticaceae varied from 6/3 in 2002 to 6/6 in 1996.The Urticaceae pollen curve is quite diverse with its presence for 8-9 months in the air and the contribution of many species in it. The pollen is present for a long time but the pollen count does not reach high concentrations.

A lot of metereological variables were entered in the correlation analysis to determine which of them gave the best correlation with the start of the peak period for Urticaceae. It was decided to use the variable" rain mean on days 11-20" to forecast the start of the peak period for Urticaceae. The coefficient correlation of this variable was equal to -0.9528** (significant at the 0.05 level (two tailed). The correlation coefficient showed that there is a negative relationship between the start of peak period for Urticaceae and the rain mean values on the period 11-20 starting from 1st of January. That means that the more rain are registered on this period, earlier the start of the peak period for Urticaceae will be observed.

The variable" rain mean on days 11-20" was entered in the linear regression to be able to forecast the start of the peak period for Urticaceae.

The simple linear regression achieved 86% explanation and have the adjusted R square =0.86 (Appendix O5) and R square=0.907.

The simple linear regression is shown below:

Start day of peak period= 156.840 - (0.997 x rain mean on days 11-20)

Table 37. Accuracy of the model predicting the start of the peak period of the Urticaceae pollen season

Year	Predicted the start of the peak period of the Urticaceae pollen season (number of days from 1st of January)	Actual start of the peak period of the Urticaceae pollen season (number of days from the 1st of January)
2003	155	157
2004	154	134

The predicted model enabled the start of the peak period of the Urticaceae to be forecast with 98 % accuracy in 2003 and 87% in 2004 (Table 37).

The years 2003 and 2004 were very different with regards to the rain amount registered respectively in January. The amount of rain registered in January 2003 was 124mm while in 2004 it was 216mm. The amount of rain registered in the period from 11-20 from days from 1st of January in year 2003 was 12.8mm while for the year 2004 was five times more, 61.2mm. Again, the year 2004 was very different in terms of meteorological parameters which also was reflected in the pollen pattern and curve for the taxa used in the current research.

8.6 THE END DATE OF THE PEAK PERIOD FOR URTICACEAE

The end date of the peak period for Urticaceae was used by following the method of Pathirane altered according to the work of Smith at al., 2005. The end date of the peak period was chosen by having an arbitrary figure (80%) of the Urticaceae pollen count. Among the different combinations of meteorological parameters that were used for the correlation analysis, the variable " rain mean on days 61-80" starting from 1st of January, gave the best correlation coefficient which was -0.99** (significant at the 0.01 level-two tailed). The coefficient correlation showed a negative relationship between the variable "rain mean on days 61-80" and the end date of the peak period for Urticaceae. The more rain recorded on the mentioned dates, the earlier the end date of the peak period for Urticaceae will be recorded. This variable was entered in the linear regression to forecast the end date of the peak period for Urticaceae. The simple linear regression used to predict the end date of Urticaceae peak period achieved an 98% explanation and have the adjusted R square =0.985 (Appendix O6- under the table Model Summary).

The simple linear regression is shown below:

End date of the peak period for Urticaceae= 270.583 – (3.855 x rain mean on days 61-80)

Table 38. Accuracy of the model predicting the end of the peak period of the Urticaceae pollen season

Year	Predicted the end of the peak period of the Urticaceae pollen season (number of days from 1st of January)	Actual end of the peak period of the Urticaceae pollen season (number of days from the 1st of January)
2003	155	157
2004	154	134

The simple linear regression used to predict the end date of the peak period for Urticaceae achieved accuracy of 94.4% in 2003 and 34% accuracy in 2004 (Table 38).

The total amount of rainfall registered in March for year 2003 was 6mm while for 2004 it was 168.1mm. This difference explained why the forecast model worked better in 2003 than in 2004. As the result of the high amount of rain in 2004 in March (which coincided with the period 61-80), the end date of the peak period for Urticaceae in 2004 was earlier.

8.7 APPRAISAL OF LONG TERM FORECAST MODELS FOR URTICACEAE

The start of Urticaceae pollen season was forecast using the temperature mean on days 1-30 or the temperature mean during January. The temperature mean was calculated as the mean between the temperature maximum and minimum in the period between1-30. It had been documented by many authors [Dominguez *et al.,* 1998; Fornaciari *et al.,* 1997, 1998;] that the meteorological parameters prior to the pollination enable the prediction of the start of the pollen season.

The model worked better in 2003 than in 2004 with the respective accuracy of 94% and 72%. It has been explained in 8.1 why the model has such variance. The year 2004 has been an exceptional year with the weather parameters reaching recordable values. The forecast model is easily applied as it takes into consideration the weather parameters prior to the Urticaceae pollen season.

The end of Urticaceae pollen season was able to be forecast using the variable rain amount on days 90-120.It seems that the total amount of rainfall during April does influence the end of the Urticaceae pollen season. It also has been observed by many authors that rainfall as well as the temperature does influence the start and duration of Urticaceae pollination [Alcala *et al.,* 1992; Fornaciari *et al.,* 1998]. The forecast model achieved an accuracy of 99% in 2003 and 81% accuracy in 2004. The difference between predicted and actual end date of Urticaceae pollen season was bigger in 2004 (56 days) than in year 2003 (five days). Again the forecast model did not work well in 2004. The detailed description of the differences between the weather features during April for both years tested has been given in 8.2.

The severity of Urticaceae pollen season was able to be forecast with the variable temperature maximum on days 91-110. It seems that the temperature maximum during the first three weeks of April does influence the severity of the Urticaceae pollen season. Dvorin *et al.,* 2001; Galan *et al.,* 2000, have demonstrated that in particular maximum daily temperature influences the amount of Urticaceae pollen in the atmosphere and the Urticaceae pollination. When the model was tested, it achieved an accuracy of 96% in 2003 and 41% in 2004.

The length of Urticaceae pollen season was able to be forecast with the means of total rainfall on days 60-90 that is the rainfall during March. This reinforces the work of many authors that correlate the weather variables prior the pollination with the duration of the pollen season [Alcala *et al.,* 1992; Fornaciari *et al.,* 1998].

The model to predict the length of the Urticaceae pollen season worked quite well with both years tested enabling an accuracy of 84% in 2003 and 89% in 2004. The difference between the predicted and actual length of Urticaceae pollen season was 26 days for 2003 and 13 days for 2004.

The start date of peak period for Urticaceae was able to be forecast with the means of variable rain mean on days 11-20. The total rain mean during the first ten days of January does influence the start of peak period for Urticaceae. The model did work well for 2003 enabling it to achieve an accuracy of 98% but a not very satisfactory result in 2004 with an accuracy of 87%. The start date of the peak period for Urticaceae in 2004 was reached in day 134 compared with day 157 for year 2003. The specific meteorological parameters during 2004 might have contributed to this difference.

The end date of the peak period for Urticaceae was able to be forecast using the variable rain mean on days 61-80. It seems that the rain mean in the first two weeks of March does influence the end date of peak period for Urticaceae. When the built model was tested in 2003 it reached an accuracy of 94.4% and 34% in 2004. Again the model did not work well at all for year 2004. The specific details for the weather parameters in this period have been given in 8.6.

The linear regression method used for the long term models for Urticaceae was based only on four years of data. This should be taken into the consideration as a longer data set will be able to produce more robust forecast models.

CHAPTER EIGHT: SECTION TWO
DEVELOPING DAILY FORECAST MODELS FOR URTICACEAE POLLEN IN TIRANA

The daily forecast model for Urticaceae pollen in Tirana was constructed for three different periods of the Urticaceae pollen season, pre-peak, peak and post-peak. The pre-peak period was considered to be the period from the start of Urticaceae pollen season with method 5% till the first day of the start of peak period, peak period was considered the period from the start of the peak period observed from Pathirane., 1975, method until 80%of accumulated values were recorded and post-peak period was considered to be the period from 80% of accumulated values till the end when 95% of accumulated values were recorded.

Three regression models were constructed as follows:

1. Multiple regression model in order to forecast the daily variations of Urticaceae pollen counts during the pre-peak period
2. Multiple regression model in order to forecast the daily variations of the Urticaceae pollen counts during the peak period
3. Multiple regression model in order to forecast the daily variations of the Urticaceae pollen counts during the post-peak period

The same meteorological variables as used in the daily grass and Olea pollen forecast were used in the daily Urticaceae pollen forecast. All the environmental variables (temperature maximum, temperature minimum, rainfall, five days running mean, four days running mean, three days running mean and two days running mean) were subject to correlation analysis in order to choose the variables with the higher correlation coefficient for entering into the multiple regression. As it has been explained in chapter six, further attempts were made to use the wind direction and wind data into the model (Appendices X9-X12). Before doing this, the Kruskal Wallace test was performed to check if these variables did make any contributions to the daily Urticaceae pollen counts. This procedure has been explained in detail in chapter six. The wind variables did not have any significant relationships with the daily Urticaceae pollen counts so they were discarded from the data set.

The multiple regressions were calculated using the relationships between the daily Urticaceae pollen counts and the meteorological data with the highest correlation coefficient for each period in order to construct models for daily Urticaceae pollen. The same conversion method as in Grass and Olea was used to obtain the normal scale expressed in p/m^3. Predicted values were squared and tested with the actual daily Urticaceae pollen counts from the 2003 and 2004 season.

It was decided to use the threshold levels for Urticaceae pollen as used in Italy (Spring project- Tab. 39)

Table 39.

Urticaceae pollen counts (p/m3)	Threshold levels used	Numerical score
2-19	low	1
20-69	moderate	2
70-300	high	3
≥ 300	very high	4

Predicted Urticaceae pollen counts obtained by correlation analysis were compared with the real (observed) data in order to specify if the models were strong enough to predict the patterns of the Urticaceae pollen counts. The correlation analysis showed that the forecast daily model for Urticaceae in the pre-peak period was sufficiently robust to explain the pattern of daily Urticaceae pollen counts.

8.8 DAILY MULTIPLE REGRESSION MODEL FOR THE PRE-PEAK PERIOD OF THE URTICACEAE POLLEN SEASON IN TIRANA

The meteorological variables used to forecast the daily Urticaceae pollen count during the pre-peak period were three-days running mean (0.654**) and temperature maximum (0.376*) with a correlation signification at the 0.01 level (2-tailed). These two meteorological variables were obtained through using the Pearson correlation (appendix P2). These two variables were used to construct a model for daily Urticaceae pollen season during the pre-peak period.

Before constructing the model a checking system for assumptions was performed.

8.8.1. **Multicollinearity**

As it has been explained in chapter six, the correlations between the variables in the model are provided in the table labeled Correlations (Appendix P1**).** The relationship between the independent variable (temperature maximum and three-days running mean) and the dependent variable (normalized Urticaceae pollen) show a clear relationship.In this case three-days running mean and temperature maximum correlate with Urticaceae pollen counts with a correlation coefficient respectively 0.654 and 0.376. The correlation between two independent variables was checked to see if it was high. The correlation coefficient between two independent variables is 0.382 that means less than 0.7, therefore two independent variables will be retain in the model.

The column headed "Tolerance" was checked also in case a value very low is detected as this presumes the possibility of multicollinearity. In this case the value was 0.854, that means not a value near value 0 (Appendix P1). Therefore this value did not appear to have violated the assumption.

8.8.2. **Outliers, Normality, Linearity, Homoscedascity, Independence of Residuals**

Through the observing of the Normal Probability Plot there are no major deviations from normality. Therefore the points does not seem to lie straight diagonal line from bottom left to top right. In the Scatterplot box, most of the scores are concentrated in the center

Also the model was checked for the Mehalanobis distance critical values. As it has been explained in chapter six, the critical values for evaluating Mahalanobis distance for two independent variables is 13.82 .Through this detecting procedure it appear to have only one outlying case above this critical value which was the value of 29.1 fro the case number 56 (appendix P3).

8.8. 3 Evaluating the model

The R square under the Model summary box (Appendix P1) has a value of 0.45 therefore the model for the daily Urticaceae pollen count during the peak period achieved approximately 45 % of explanation. Adjusted R Square has a value of 0.43. Under the table Coefficients the Beta value are larger for three- day running mean than the temperature maximum presuming that the variable three- days running mean do contribute more into the model than the variable temperature maximum.

The sample size for the peak period does fulfill the requirement from Tabanich *et al.,* 2001.

Predicted daily Urticaceae pollen in the pre-peak period
= 0.303+ (0.115 x three-days run + 0.056x Tmax)

The predicted and actual daily Urticaceae pollen counts were converted into numerical scores. Percent accuracy obtained was 90% in 2003 and 89%in year 2004. Then the predicted and actual Urticaceae pollen count were subjected to correlation analysis to check if the constructed model was able to predict the pattern of daily Urticaceae pollen counts during the pre-peak period. The constructed model was able to predict the pattern of daily Urticaceae pollen counts during the pre-peak period

Through using the Excel program the actual and predicted Olea pollen count were compared (Fig. 31, 32).

Fig. 31

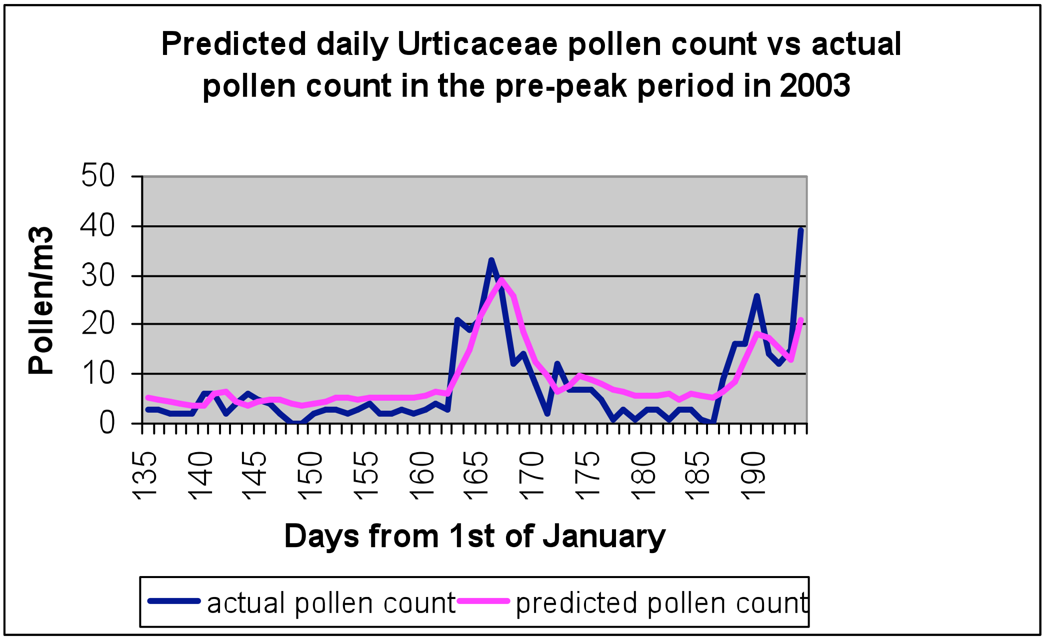
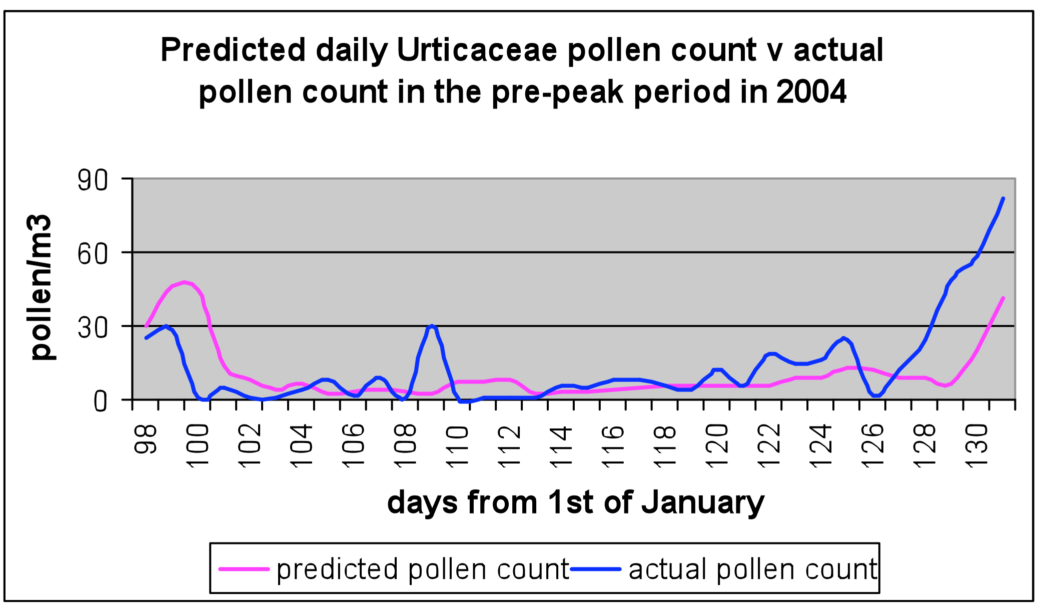

Predicted daily Urticaceae pollen count vs actual pollen count in the pre-peak period in 2003
Pollen/m3
50
40
30
20
10
0
135
140
145
150
155
160
165
170
175
180
185
190
Days from 1st of January
actual pollen count
predicted pollen count

Fig.32


Predicted daily Urticaceae pollen count v actual pollen count in the pre-peak period in 2004
pollen/m3
90
60
30
0
98
100
102
104
106
108
110
112
114
116
118
120
122
124
126
128
130
days from 1st of January
predicted pollen count
actual pollen count

8.9 DAILY MULTIPLE REGRESSION MODEL FOR THE PEAK PERIOD OF THE URTICACEAE POLLEN SEASON IN TIRANA

The meteorological variables used to forecast the daily Urticaceae pollen count during the peak period were two-days running mean (0.655**) and temperature minimum(-0.288*) with a correlation signification at the 0.01 level (2-tailed). These two meteorological variables were obtained through using the Pearson correlation (appendix P 5). These two variables were used to construct a model for daily Urticaceae pollen season during the peak period.

Before constructing the model a checking system for assumptions was performed.

8.9.1 Multicollinearity

As it has been explained in chapter six, the correlations between the variables in the model are provided in the table labeled Correlations (Appendix P4). The relationship between the independent variable (temperature minimum and two-days running mean) and the dependent variable (normalized Urticaceae pollen) show a clear relationship. In this case two-days running mean and temperature minimum correlate with Urticaceae pollen counts with a correlation coefficient respectively 0.655 and -0.288. The correlation between two independent variables was checked to see if it was high. The correlation coefficient between two independent variables is -0.177 that means less than 0.7 therefore two independent variables will be retained in the model.

The column headed "Tolerance" was checked also in case a very low value is detected as this presumes the possibility of multicollinearity. In this case the value was 0.969 that means not a value near value 0. Therefore this value did not appear to have violated the assumption.

8.9.2. Outliers, Normality, Linearity, Homoscedascity, Independence of Residuals

Through the observing of the Normal Probability Plot there are some minor deviations from normality. Therefore the points doesn't seem to lie straight diagonal line from bottom left to top right. In the Scatterplot box, most of the scores are concentrated in the center.

Also the model was checked for the Mehalanobis distance critical values. As it has been explained in chapter six, the critical values for evaluating Mahalanobis distance for two independent variables is 13.82.Through this detecting procedure it did not appear to have any outlying case above this critical value (appendix P6).

8.9.3 Evaluating the model

The R square under the Model summary box (Appendix P4) has a value of 0.459 therefore the model for the daily Urticaceae pollen count during the peak period achieved approximately 46 % of explanation. Adjusted R Square has a value of 0.456. Under the table Coefficients the Beta value are larger for two- day running mean than the temperature minimum presuming that the variable two- days running mean do contribute more into the model than the variable temperature minimum.

The sample size for the peak period does fulfill the requirement from Tabanich *et al.,* 2001.

Predicted daily Urticaceae pollen in the peak period

= 2.965+ (0.126x two-days run - 0.105x Tmin)

The predicted and actual daily Urticaceae pollen counts were converted into numerical scores. Percent accuracy obtained was 90% in year 2003 and 79 %in year 2004. Then the predicted and actual Urticaceae pollen count were subjected to correlation analysis to check if the constructed model was able to predict the pattern of daily Urticaceae pollen counts during the peak period. The constructed model was able to predict the pattern of daily Urticaceae pollen counts during the peak period

Through using the Excel program the actual and predicted Olea pollen count were compared (Fig. 33, 34).

Fig. 33

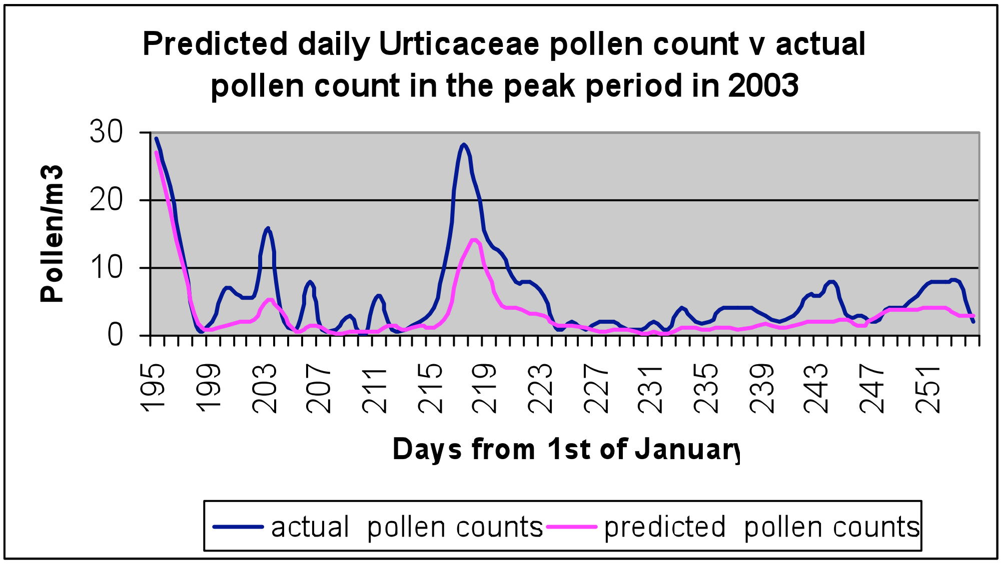
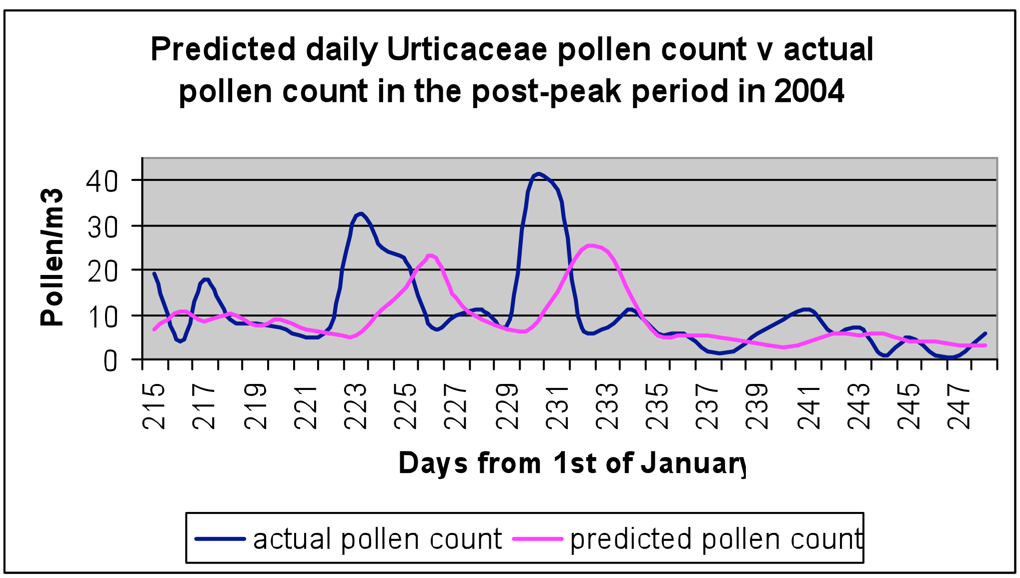

Predicted daily Urticaceae pollen count v actual pollen count in the peak period in 2003
Pollen/m3
30
20
10
0
195
199
203
207
211
215
219
223
227
231
235
239
243
247
251
Days from 1st of January
actual pollen counts
predicted pollen counts

Fig.34


Predicted daily Urticaceae pollen count v actual pollen count in the post-peak period in 2004
Pollen/m3
40
30
20
10
0
215
217
219
221
223
225
227
229
231
233
235
237
239
241
243
245
247
Days from 1st of January
actual pollen count
predicted pollen count

8.10 MULTIPLE REGRESSION MODEL FOR THE POST- PEAK PERIOD OF THE OLEA POLLEN SEASON IN TIRANA

The meteorological variables used to forecast the daily pollen counts for the post-peak period were three days running mean and temperature minimum. This relationship was found when the Pearson correlation was performed. The variable three-days running mean achieved an correlation coefficient of 0.558** with the normalized Urticaceae pollen counts while the temperature minimum achieved and correlation coefficient of 0.298** (correlation is significant at the 0.01 level (two-tailed) (appendix P8).

8.10.1 Multicollinarity

Through the observation of the correlation between the independent variables no assumptions were detected.
The value under the column Tolerance is 0.901 therefore the model has not violated the assumption (Appendix P7).

8.10.2 Outliers, Normality, Linearity, Homoscedascity, Independence of Residuals

Through the observing of the Normal Probability Plot there are minor deviations from normality. In the Scatterplot box, most of the scores are concentrated in the centre.
Outliers have been detected through the Mahalanobis distances produced by the multiple regression programs. The critical chi- value for two independent variables is 13.82 the model has not outlying cases (Appendix P9).

8.10.3 Evaluating the model

The R square under the Model summary box (Appendix P7) has a value of 0.328 therefore the model for the daily Urticaceae pollen count during the post- peak period achieved app 32.8 % of explanation. Adjusted R Square has a value of 0.328. Under the table Coefficients the Beta value are larger for three- day running mean than the temperature minimum.

The sample size for the post- peak period fulfills the requirement from Tabanich *et al.,* 2001.

Predicted daily Urticaceae pollen during the post-peak period = 0.407+ (0.117 x three-day)- (0.058x Tmin)

The predicted and actual daily Urticaceae pollen counts were converted into numerical scores. Percent accuracy obtained was 65% in year 2003 and 67% in year 2004. Then the predicted and actual Urticaceae pollen count were subjected to correlation analysis to check if the constructed model was able to predict the pattern of daily Urticaceae pollen counts during the post-peak period. The correlation analysis has shown that the predicted Urticaceae pollen during the post-peak period did not predict any trend in the Urticaceae pollen. Through using the Excel program the actual and predicted Urticaceae pollen count were compared (Fig. 35, 36).

Fig.35

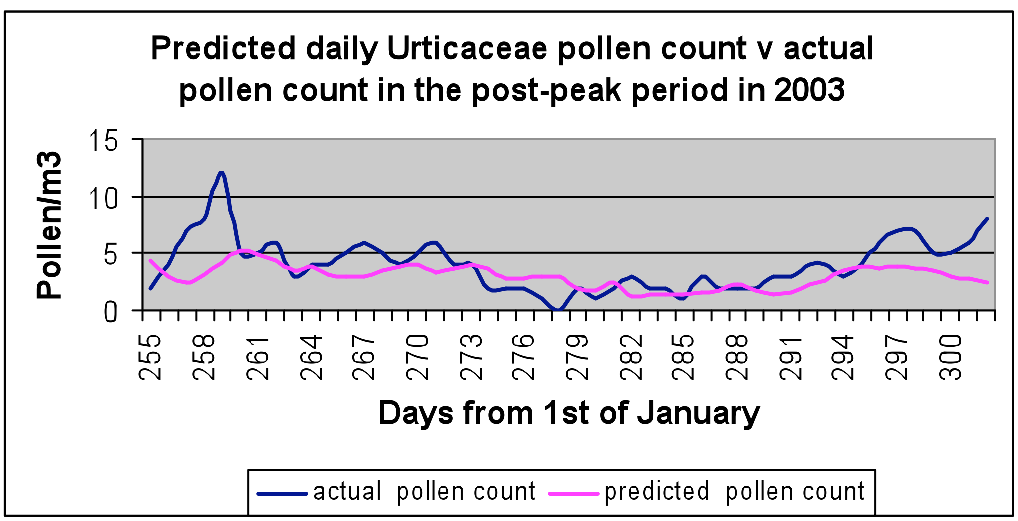
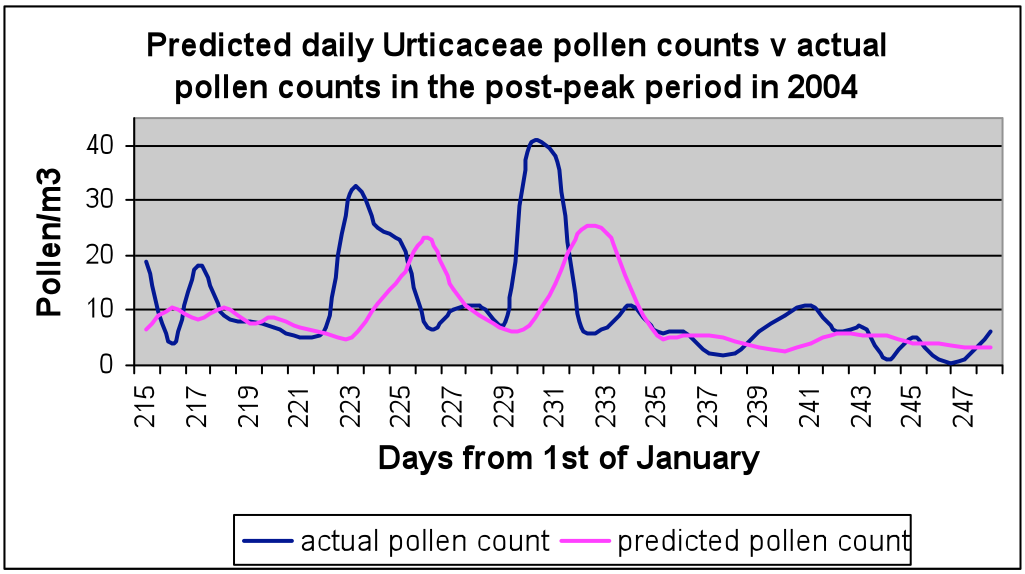


Fig.36


Predicted daily Urticaceae pollen counts v actual pollen counts in the post-peak period in 2004
Pollen/m3
40
30
20
10
0
215
217
219
221
223
225
227
229
231
233
235
237
239
241
243
245
247
Days from 1st of January
actual pollen count
predicted pollen count

CHAPTER EIGHT: SECTION THREE
DEVELOPING DAILY FORECAST MODELS FOR URTICACEAE POLLEN IN TIRANA ON THE NON-RAINY DAYS

INTRODUCTION

The short term daily forecast model for Urticaceae pollen in Tirana on the non-rainy days was constructed for three different periods of the Urticaceae pollen season, pre-peak, and peak period. The model for post-peak period was not constructed as it did not show good results. The methodology on how the Urticaceae pollen season has been explained in details in Chapter 4.4. Also the justification on how the Urticaceae pollen season has been divided on three periods has been explained in chapter eight section two.

Two regression models were constructed as follows:

1. Multiple regression model in order to forecast the daily variations of Urticaceae pollen counts on the non-rainy days during pre-peak period
2. Multiple regression model in order to forecast the daily variations of the Urticaceae pollen counts on the non-rainy days during the peak period

The same meteorological variables as in the daily Urticaceae pollen forecast that included the rainy days were used to predict the daily Urticaceae pollen count on the non-rainy days besides the variable rainfall which was excluded from the dataset. All the environmental variables (temperature maximum, temperature minimum, five days running mean, four days running mean, three days running mean and two days running mean) were subject to correlation analysis in order to choose the variables with the higher correlation coefficient for entering into the multiple regression.

The multiple regressions between the daily Urticaceae pollen counts on the non-rainy days and the meteorological data with the highest correlation coefficient were carried out for each period in order to construct models for the daily Urticaceae pollen. A conversion of all the forecast models obtained from the equation was made to the normal work scale (p/m^3). Predicted values were squared and tested with the actual daily Urticaceae pollen counts from the 2003 and 2004 season.

It was decided to use the threshold for Urticaceae pollen as used in Italy (Table 40)

Table 40.

Urticaceae pollen counts (p/m3)	Threshold used	Numerical score
2-19	low	1
20-69	moderate	2
70-300	high	3
≥ 300	very high	4

Predicted Urticaceae pollen counts were compared with the real (observed) data obtained by correlation analysis in order to specify if the models were strong enough to predict the patterns of the Urticaceae pollen counts.

8.11 DAILY MULTIPLE REGRESSION MODEL FOR THE PRE-PEAK PERIOD OF THE URTICACEAE POLLEN SEASON ON THE NON-RAINY DAYS IN TIRANA

The meteorological variables used to forecast the daily Urticaceae pollen count on the non-rainy days during the pre-peak period were 3-days running mean (0.575**) and four running mean (0.573*) with a correlation signification at the 0.01 level (2-tailed). These two meteorological variables were obtained through using the Pearson correlation (Appendix Q2). These two variables were used to construct a model for the daily Urticaceae pollen season during the pre-peak period on the non-rainy days.

Before constructing the model a checking system for assumptions was performed.

8.11.1 Multicollinearity

The correlations between the variables in the model were provided in the table labeled Correlations (Appendix Q1**).** The relationship between the independent variables (three and four-days running mean) and the dependent variable (normalized Urticaceae pollen) showed a clear relationship. The correlation between two independent variables and independent variable was checked to see if was high. In this case the correlation was .970 between those two mentioned metereological parameters. The column headed "Tolerance" was checked in case a value very low is detected as this presumes the possibility of multicollinearity. In this case the value was 0.058 so should be regarded with precaution.

8.11.2. Outliers, Normality, Linearity, Homoscedascity, Independence of Residuals

Through the observing of the Normal Probability Plot there are no major deviations from normality. Therefore the points do seems to lay straight diagonal line from bottom left to top right. In the Scatterplot box, most of the scores are concentrated in the centre. There are two cases above the critical value, the value 18 for the case number 67 and the value 16 for the case number 65.

8.11.3. Evaluating the model

The R square under the Model summary box (Appendix Q1) has a value of 0.334, therefore the model for the daily Urticaceae pollen count during the peak period achieved app 33.4 % explanation. Adjusted R Square has a value of .321. The sample size for the peak period does not fulfill the requirement from Tabanich *et al.,* 2001.

Predicted daily Urticaceae pollen on the non-rainy days for the pre-peak period = 2.012+ (0.050 x four-days running mean)- (0.061x three- days running mean)

The predicted and actual daily Urticaceae pollen counts were converted into numerical scores. Percent accuracy obtained was 90% in year 2003 and 91%in 2004. Through using the Excel program the actual and predicted Urticaceae pollen count were compared (Fig. 37, 38).

Fig.37

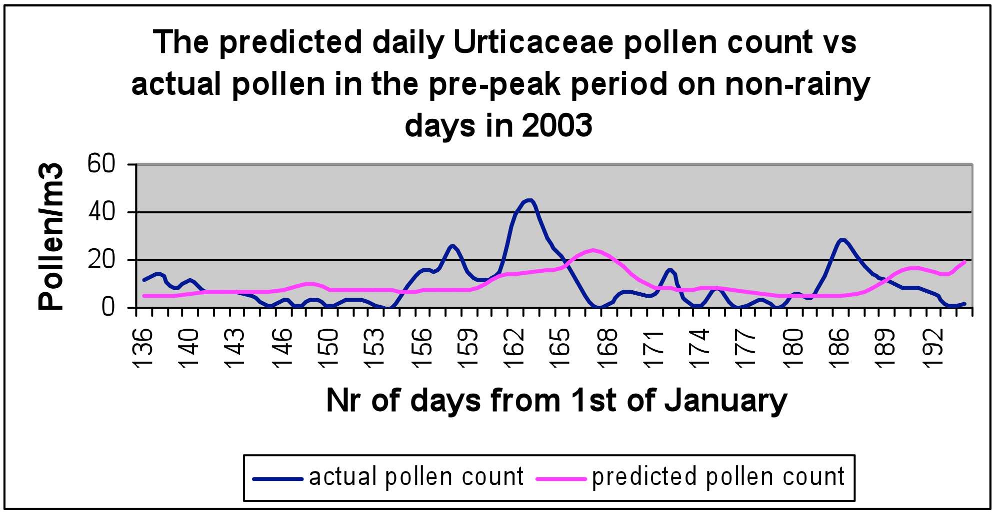
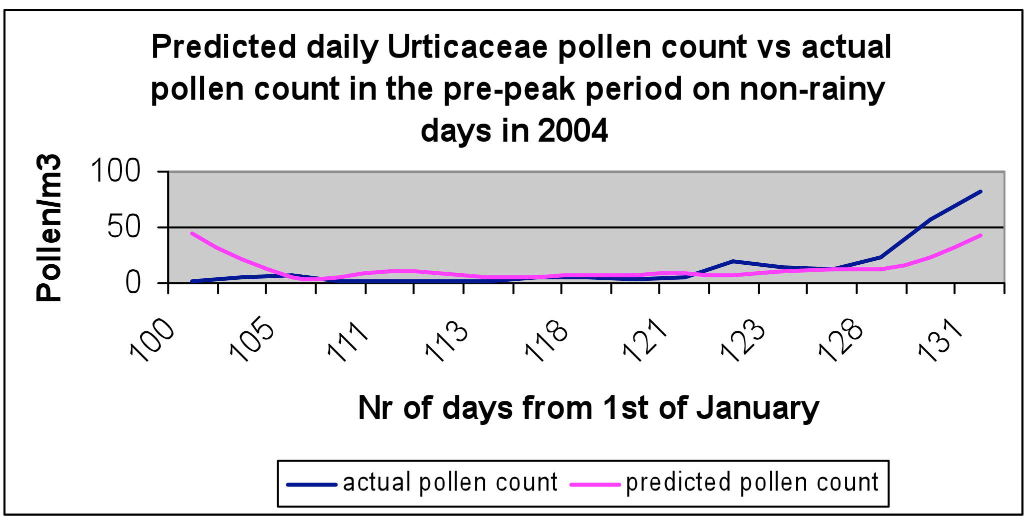

The predicted daily Urticaceae pollen count vs actual pollen in the pre-peak period on non-rainy days in 2003
Pollen/m3
60
40
20
0
136
140
143
146
150
153
156
159
162
165
168
171
174
177
180
186
189
192
Nr of days from 1st of January
actual pollen count
predicted pollen count

Fig.38


Predicted daily Urticaceae pollen count vs actual pollen count in the pre-peak period on non-rainy days in 2004
Pollen/m3
100
50
0
100
105
111
113
118
121
123
128
131
Nr of days from 1st of January
actual pollen count
predicted pollen count

8.12 MULTIPLE REGRESSION MODEL FOR THE PEAK PERIOD OF THE URTICACEAE POLLEN SEASON IN TIRANA ON THE NON-RAINY DAYS

The meteorological variables used to forecast the Urticaceae daily pollen counts on the non-rainy days for the peak period were two days running mean (0.652**) and temperature minimum(-0.342**). The correlation was significant at the 0.01 level (two-tailed). This relationship was found when the Pearson correlation was performed (Appendix Q5). The same checking procedure was used as mentioned in 6.5 and 6.6.

1. Multicollinarity

Through the observation of the correlation between the independent variables no assumptions were detected.

The value under the column Tolerance is 0.964 therefore the model has not violated the assumption (Appendix Q4).

8.12.2 Outliers, Normality, Linearity, Homoscedascity, Independence of Residuals

Through the observing of the Normal Probability Plot there are no major deviations from normality. In the Scatterplot box, most of the scores are concentrated in the center.

Outliers have been detected through the Mahalanobis distances produced by the multiple regression programs. The critical chi- value for two independent variables is 13.82, the model has two outlying cases, the value 23.8 for the case number 24 and the value 17.5 for the case number 1 (Appendix Q6).

8.12.3 Evaluating the model

The R square under the Model summary box (Appendix Q4) has a value of 0.475, therefore the model for the daily Urticaceae pollen count during the peak period achieved app 47.5% explanation. Adjusted R Square has a value of 0.471. Under the table Coefficients, the Beta values are larger for two- day running mean than the temperature minimum.

The sample size for the peak period fulfills the requirement from Tabanich *et al.,* 2001.

Predicted daily Urticaceae pollen on the non-rainy days for the peak period = 3.377+ (0.127 x two-days running mean) - (0.127x temperature minimum)

The predicted and actual daily Urticaceae pollen counts were converted into numerical scores. Percent accuracy obtained was 85% in year 2003 and 89% in 2004. Then the predicted and actual Urticaceae pollen count were subjected to correlation analysis to check if the constructed model was able to predict the pattern of the daily Urticaceae pollen counts during the pre-peak period. The correlation analysis has shown that the predicted pollen Urticaceae during the peak period did predict the trend in the Urticaceae pollen. Through using the Excel program the actual and predicted Urticaceae pollen count were performed (Fig. 39, 40).

Fig. 39

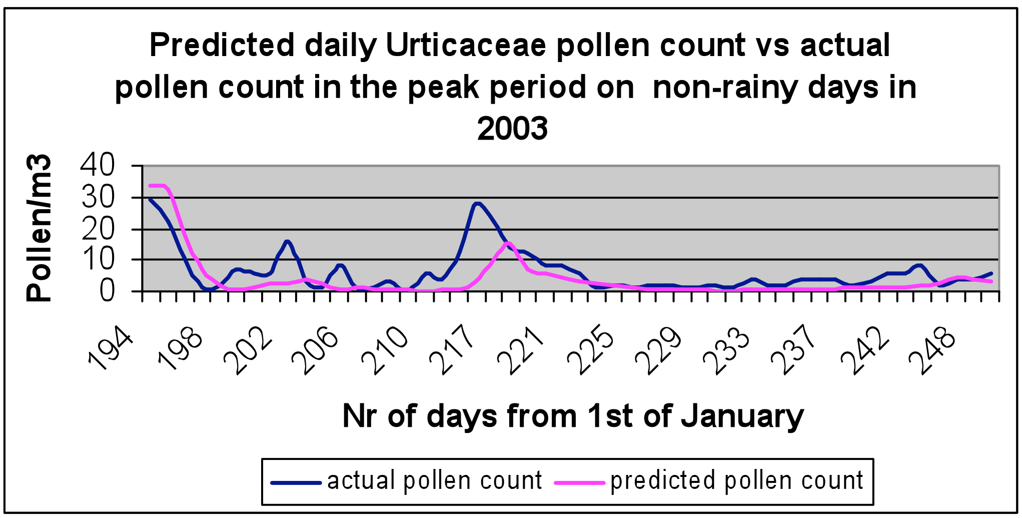
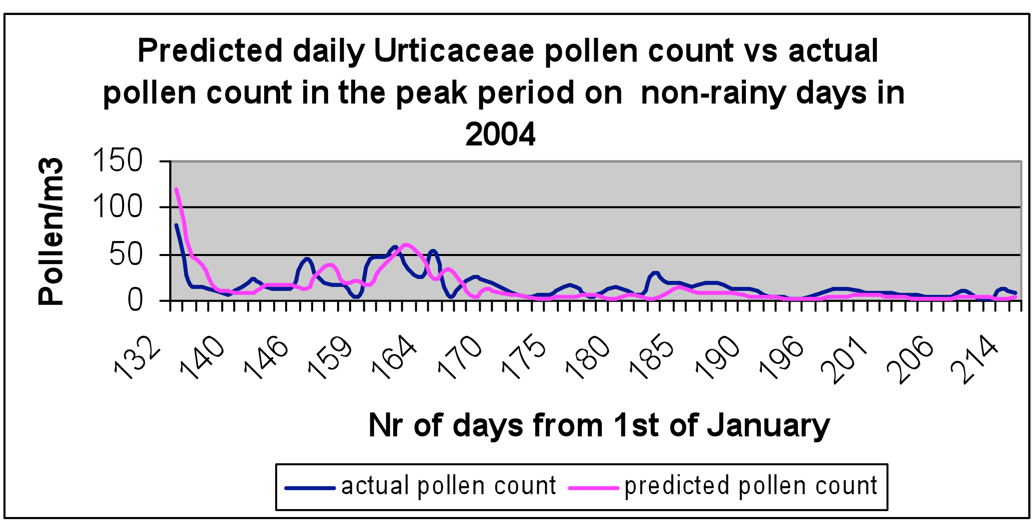


Fig.40



8.13 APPRAISAL OF SHORT TERM FORECAST MODELS FOR URTICACEAE INCLUDING THE MODELS ON NON-RANY DAYS

The forecast models for the pre-peak period for Urticaceae was based on the meteorological variables three days running mean and temperature maximum. The correlation coefficient was higher for the three days running mean of pollen counts than the temperature maximum. The report from Galan *et al.,* 2000, demonstrated that there was a statistically based correlation between maximum daily temperature and Urticaceae pollen concentration. The rainfall did not seem to play a role to the Urticaceae pollen concentrations. Fornaciari *et al.,* 1992 reported that correlating the rainfall and the pollen concentration were difficult and Urticaceae pollen does not seem to be influenced by this parameter. Also Corden & Millington, 1991 conluded that rainfall showed no appreciable correlation with Urticaceae pollen level. The model was able to reach 32% explanation.

The forecast model worked better for 2003 than 2004. The accuracy of the model was 90% in 2003 while was 89% in 2004.

The model for the peak period was based on the meteorological variables such as two days running mean of pollen counts and temperature minimum. The relationship of temperature minimum with the daily Urticaceae pollen counts during the peak period is negative which lead to the conclusion that the increases of the temperature minimum in the atmosphere produce less Urticaceae pollen concentrations and vice versa. Galan *et al.,* 2000, also showed good correlation between the daily Urticaceae pollen counts and minimum temperature. The author also reported good relationship between the daily Urticaceae pollen counts and the pollen concentrations of the previous days even this relationship was stronger on the non-rainy days. The accuracy of the model was 90% in 2003 and 79% in 2004. The model for the peak period was able to reach 45.6 % of explanation.

Again the temperature minimum and three days running mean of pollen counts were the meteorological parameters used for constructing forecast model for Urticaceae pollen during the post peak period. The model for the peak period was able to reach 43.8 % of explanation.

When the model was tested in 2003 it achieved accuracy of 65% and in 2004 a accuracy of 67%.

It should be noted that Urticaceae pollen curve is long and persists until the autumn. In autumn, the effect of humidity has been shown to be significant as days with high relative humidity make the pollen heavier, preventing them from flying long distance and therefore partially explaining the decline in airborne pollen concentrations [Trigo *et al.,* 1996]. The humidity, sunlight hours and temperature are the best parameters for determining the Urticaceae daily pollen count in autumn [Galan *et al.,* 2000]. Also some attempts has been made to correlate the daily Urticaceae pollen count and the diurnal temperatures.

[Crimi *et al.,* 2004] as an increase in diurnal temperatures range could be responsible for a dehydration of Urticaceae pollen resulting in a loss in mass.

It should be mentioned that the start of peak period for Urticaceae was defined according to [Gutierrez *et a*l., 1999], by determining graphically the daily Urticaceae pollen counts using the percentages values as the Pathirane, 1975 has used. The pollen peak period is between the inflections of a sigmoid curve. This method is allow to observe the differences between years but is subjective as the start of peak period can be calculated by using the cumulative percentages values when the season has finished. The end of peak period was used chousing an arbitrary figure as 80%, as Smith *et al.,* 2005 have used. More work needs to be done in finding a more suitable method to determine the start of peak period for Urticaceae as well as grass and Olea.

The models for the pre-peak period on non-rainy days for Urticaceae showed that the pollen concentration of the previous days (three and four) gave the best correlation coefficient. During the pre-peak period for the Urticaceae in 2003 there were 20 days with rainfall while in 2004 were 17 days with rainfall. These variables were used for the regression analysis which gave 32.1% explanation and was the same explanation that was reached for the daily Urticaceae pollen counts including the rainy days.

The temperature minimum and three days running mean of pollen counts were the variables that were used for the model of peak period on non-rainy days. During the peak period for Urticaceae in 2003 there were 11 days with rainfall while in 2004 there were 17 days with rainfall.

The model gave 47.1% explanation compared with 45.6% in the model that included the rainy days. The model for non-rainy days increases the level of explanation by 2% while the model for the pre-peak increases the level of explanation by 0.1%. In both cases (pre-peak and peak) the models constructed without using rainy days increased the accuracy of prediction.

CHAPTER NINE: NEURAL NETWORKS

This study is related to the aim of developing neural network models for forecasting daily pollen counts for Grass, Olea and Urticaceae in the Tirana area. Also it analyses and compares the accuracy of these models with those obtained from regression models for the same taxa. It will help to improve the accuracy of the models for the mentioned taxa in the Tirana area.

9.1 NEURAL NETWORK BACKGROUD AND LITERATURE REVIEW

A lot of predictive models have been used recently in Aerobiology to predict the pollen concentrations in the air. Several types of forecasting methods have been used for this purpose. These include analytical models [Moseholm *et al., 1987*], which are based on various equations describing the phenomena of emission and dispersion of pollen in the air through combining different parameters related to the plant observations and weather conditions. The general experience has been that the lack of the parameter values makes this method difficult. Another popular approach is that of statistical models (linear and multiple regression models) which are mostly related to the close relationship of pollen data and meteorological data [Emberlin *et al.,* 1998, Laaidi *et al.,* 2003, Galan *et al.,* 2001 a]. Alternatively some authors have used time series analysis [Moseholm *et al.,* 1987] which does not assume the knowledge of the structural relationships between variables involved in the process but is mostly related to the analysis of the past observations of a variable to develop a model for understanding the future trend better.

Recently some attempts have been made to use the neural network method to forecast the pollen concentrations of some allergenic taxa in the air [Sanchez-Mesa *et al.,* 2002].

Mesa *et al.,* in 2002, were able to forecast daily pollen concentrations in the air by using meteorological data and pollen counts from previous days as independent variables by using a neural network method.

Linear regression models and neural methods models were used for this type of study which included a set of 20 years data from 1982-2001. The years were classified into groups. It was observed that cumulative values and pollen values from previous days were the most important factors into the model. The neural network equations produced better results than linear regression equations in predicting the daily airborne Poaceae pollen concentrations. It was also suggested that the new method based on the neural network is a step toward the automation of the pollen forecast process.

Ranzi *et al.,* 2003, also used a neural network model for grass pollen concentrations in Emilia-Romagna, Italy for a data set of 20 years. Input variables were daily temperature (maximum and minimum) and rainfall in addition to combinations of these variables and their thresholds. Thresholds were chosen with statistical techniques. The neural method was able to predict also the anomalous years. The model was able to predict the grass pollen concentrations and was also able to understand that the relationships between pollen concentrations and meteorological situations are independent from site. This means that such models can understand the differences in different areas.

The use of neural network in Aerobiology is in its infancy and in its experimentation stage. There are only a few examples of its use in aerobiology and more work needs to be done in this method in future.

9.2 INTRODUCTION

The origin of the development of technology of the Network of Neurons is derived from the great will to develop an artificial system that is capable of carrying out "intelligent" tasks similar to those in the human brain. Neural networks are computational models, the main characteristic of which is their capacity for learning by example. The meaning is that by using a neural network there is no need to programme how the outputs are obtained given certain inputs but rather examples are shown of the relations between inputs and outputs and the neural network will learn the existing relationship between the two by means of a learning algorithm. The learning is already materialized on the network's topology and the in value of its connections. As soon as the neural network has learnt how to carry out the desired function it can be used for example input values for which the output is unknown can be entered and the neural network will calculate the output.

An artificial neural network (ANN), also called a simulated neural network (SNN) or commonly just neural network (NN) which is an interconnected group of artificial neurons that uses a mathematical or computational model for information processing based on a connectionist approach to computation. In most cases, an ANN is an adaptive system that changes its structure based on external or internal information that flows through the network [Sarle *et al.,* 1994].

Neural networks are made of units that are often assumed to be simple in the sense that their state can be described by single numbers, their "activation" values. Each unit generates an output signal based on its activation. Units are connected to each other very specifically, each connection having an individual "weight" (again described by a single number). Each unit sends its output value to all other units to which they have an outgoing connection. Through these connections, the output of one unit can influence the activations of other units. The unit receiving the connections calculates its activation by taking a weighted sum of the input signals (i.e. it multiplies each input signal with the weight that corresponds to that connection and adds these products). The output is determined by the activation function based on this activation (e.g. the unit generates output or "fires" if the activation is above a threshold value). Networks learn by changing the weights of the connections.

9.3 DEFINITION

The neuron is an algebraic, non linear and parametric function with values.

Although all variables where a neuron acts are qualified as intrusions of neurons and functional values.

An introduction of a mathematic network of neurons is: $y = f(x_1, x_2, \ldots, x_n ; w_1, w_2, \ldots, w_n)$ where $\{x_i\}$ *is the entry and* y *is the exit.*

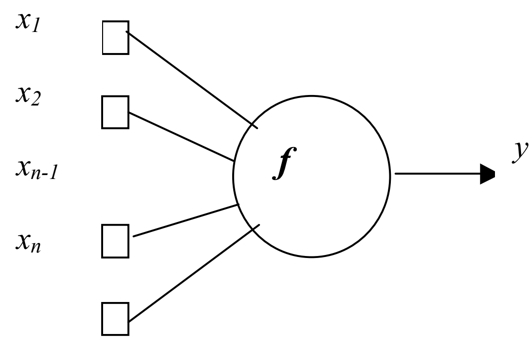


Fig. 41 – A simple introduction of the network of neurons

The parameters are related to neurons' entries. In this case the exit of neurons is a non-linear function combined from entry $\{x_i\}$, equilibrated *from parameters* $\{w_i\}$, called « weight » or « synaptiques weight ». In neural network the linear combination at the neurons' exit is called « potential ». In general a constant term or "bias" has been added to the « potential » (v).

$$v = w_0 + \sum_{i=1}^{n-1} w_i x_i$$

Function f *is called the* « activation function ». In general it is used for f a sigmoid function, which is a symmetric in relation to the origin, similar to the hyperbolic tangent, arctangent function or hyperbolic sinus. The exit of the network of neurons in the majority of applications has as an equation:

$$y = th(w_0 + \sum_{i=1}^{n-1} w_i x_i)$$

9.4 THE STATIC NEURAL NETWORK

The static neural network is represented by some neurons that are related together, where the information flows from entries toward exits and is not allowed to return.

Neurons, which make the last calculation of the composition of functions, are called exit neurons and those which make mediator calculations are called hidden neurons. The layer is called a group of neurons that are located at the same level of connections.

A functional link network introduces an extra hidden layer of neurons but there is still only one layer of weights to be estimated. If the model includes estimated weights between the inputs and the hidden layer and the hidden layer uses nonlinear activation functions such as the logistic function, the model becomes genuinely nonlinear for example nonlinear in the parameters.

The resulting model is called a Multilayer percepton or MLP. Such neural networks are direct with layers in which neurons have an activation sigmoid function. For this reason they are called also percepton with many layers or MLP. The number of hidden neurons can be less than the number of inputs or outputs. MLS can be used when there is little knowledge about the form of the relationship between the independent and dependent variables.

MLS are usually trained by an algorithm called the generalised delta rule which computes derivatives by a simple application of the chain rule called backpropagation.

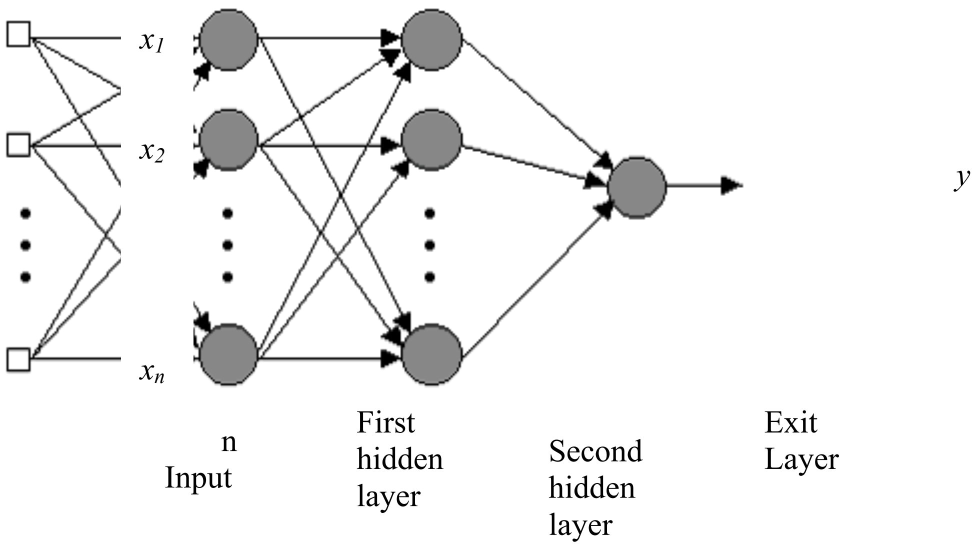


Fig. 42 – The presentation of the hidden layers of a network of neurons or multi - layer perceptron

The direct neural network or static one has been used in the current research.
In contrast to the static networks there are recurrent neural networks. These are not appropriate for the current research.

9.5 MULTI-LAYER PERCEPTON

The structure of neural networks stimulates the transmission of information in the human brain. The cells or units receive a pattern of information in input, elaborate it through an activation function and then produce an output value. The connections link the various cells and have a variable value called synaptic weight. The topology of these connections allows a high variety of networks. For example, the feed-forward multi layer Percepton (MLP) has:

1. An input layer with a number of cells equal to the number of independent variables. They simply receive the input value and transmit it to the cells of the next layer (multiplicated by the weight of each connection).

2. A hidden layer or more: at each hidden node (its number is variable and is a parameter of the network), a weighted linear combination of the inputs is summed and then a non-linear transformation is applied.
3. The output layer with a number of cells equal to the dependent variable

The training process of the neural networks involves adjusting the weights till a desired input/output relationship is obtained. The majority of adaption learning algorithms are based on Widrow-Hoff back-propagation algorithm [Ranzi *et al.,* 2003]. The input of a particular element is calculated as the sum of the input values multiplied by the connection strength (synaptic weights).

$$Hj = \sum_{i=1}^{m} w_{ji} Ii$$

Where Hj is a hidden layer, Ij is the input cell, m is the number of input cells, wij is the synaptic strength between ith input cells and jth hidden layer cell.

The value of each cell is passed through a nonlinear sigmoidal function. This function is used because it permits the network to perform a high dimensional, non-linear approximation to the data. Indeed this allows the construction of quite arbitrary, non-predetermined functions by the network.

$G(x)=1/1+e^{-x}$

The output of the hidden layer was the input to the cells located in the final output layer of the network. Since the cell in the final output layer received inputs from all the previous layer cells, the output of whole network at a given p pattern Op can be described as follows:

$$Ok^{P} = g\left(\sum_{i=1}^{m} wkjg\left(\sum_{i=1}^{m} wjiIip + 0j\right)\right)$$

Where m is the number of input cells, n is the number of hidden cells, wkj are the weights between the hidden and output layer, wji are the weights between the input and hidden layer cells, 0j is the threshold of the jth hidden layer cell, k is equal to 1 in case of a single output.

The error of the network for identifying a given pattern p is calculated as

$$E = \sum (Op - d^{P})2$$

Where dP is the desired output, Op is the actual output of the network.

9.6 MAIN FEATURES OF THE NEURAL NETWORKS

In practice, the neural network does have advantages regarding the conventional approximations as they do require less variables for the solution of a problem. This feature is a crucial aspect of neural networks which makes them approximal non-linear. Some of the NN features are as:

- generalising
- degradation
- adaptation
- parallelism

The neural networks (NN) literature distinguished between supervised and unsupervised learning. In supervised learning the goal is to predict one or more target variables from one or more input variables. Supervision consists of the use of target values in training. Supervised learning is usually some form of regression or discriminant analysis. MLPs are the most common variety of supervised network.

In unsupervised learning, the NN literature claims that there is not a target variable and the network is supposed to train itself to extract "features" from the independent variables. The goal in most forms of unsupervised learning is to construct feature variables from which the observed variables which are really both input and target variables can be predicted.

9.7 TERMINOLOGY USED IN THE NEURAL NETWORKS

Neural networks have their own unique terminology which is slightly different from those used in other statistical models. The most frequently used terminology in the neural networks models is as below:

- variables are called features
- independent variables are called inputs
- predicted values are called outputs
- dependent variables are called targets or training values
- residuals are called errors
- estimation is called training, learning, adaption or self-organisation
- an estimation criterion is called an error function or cost function
- observations are called patterns or trainings pairs
- parameters estimates are called synaptic weights
- interactions are called higher- order neurons
- transformations are called functional links
- regression are called supervised training

- extrapolation is called as generalization

The statistical terms”sample” and “population” do not have their equivalent terms in neural networks. However, the data are grouped most often as a training set and a test set for cross-validation.

9.8 MATERIALS AND METHODS

The pollen and meteorological data used for the neural network (NN) method has been the same data set as those used for the regression model (temperature maximum, temperature minimum and rainfall). The data set for training included the data of the years of 1995, 1996, 1998, 2002, 2003 for Grass, Olea and Urticaceae. The year 2004 was used as a test year.

Input variables for the mentioned taxa were meteorological parameters such as temperature maximum, temperature minimum and rainfall. The pollen data were normalized according to the method described on the methodology chapter 2. The NN used in the research for Grass, Olea and Urticaceae is a direct neural network (static) with one neuron in the hidden layer.

The topology of the models consists of an input layer, hidden layer and output layer. The input layer is composed of three neurons, the hidden layer is composed of one layer with 99-117 neurons for all the taxa and the output layer is composed of one neuron (the predicted pollen data).

9.8.1 Determination of the hidden layer numbers

The hidden layer was chosen with one neuron for all the taxa. Hornik et al.,1989, suggest that any bounded, sufficiently regular function can be approximated uniformly with arbitrary accuracy in a finite region of variable pace, by a neutral network with a single layer of hidden neurons having the same activation function, and a linear output neuron.

The number of input and output nodes corresponds to the number of network inputs and desired outputs, respectively. The choice of the number of hidden layers and the nodes in the hidden layer(s) depends on the network application. Selection of the number of hidden layers is a critical part of designing a network and is not as straightforward as input and output layers. There is no mathematical approach to obtain the optimum number of hidden layers, since such selection generally fall into the application oriented category. However, the number of hidden layers can be chosen based on the training of the network using various configurations, and selection of the configuration with the fewest number of layers and nodes which still yield the minimum root-mean-squares (RMS) error quickly and efficiently. In general, adding a second hidden layer improves the network's prediction capability due to the nonlinear separability property of the network. However, adding an extra hidden layer commonly yields prediction capabilities similar to those of two-hidden layer networks, but requires longer training times due to the more complex structures. Although using a single hidden layer is sufficient for solving many functional approximation problems, some problems may be easier to solve with a two hidden-layer configuration.

The respective topology has been explained for each taxon separately in section 9-Results.

9.8.2 Determination of number of neurons in the hidden layer

Determination of the number of neurons in the hidden layer was done automatically based on the rule that the number of weights should be less than a tenth of the number of training samples [Weigend *et al.,* 1991]. Another rule of thumb known as the Baum-Haussler rule [Baum and Haussler, 1998] can be used to determine the number of hidden layer neurons.

9.8.3 How to stop training

The training network needs time to be stopped and so in many cases it has stopped after a number of epochs or number of observations as the tables 41-49, have shown.

The stop criterion is a fundamental aspect of training. The simple ideas of capping the number of iterations or of letting the system train until a predetermined error value are not recommended. The reason is that the ANN should perform well in the test set data; i.e., the system needs to perform well in data it never saw before (good *generalization*) [Bishop, 1995]. The error in the training set tends to decrease with iteration when the ANN has enough degrees of freedom to represent the input/output map. However, the system may be remembering the training patterns (overfitting) instead of finding the underlying mapping rule. This is called overtraining. To avoid overtraining the performance in *a* validation set, i.e., a set of input data that the system never saw before, must be checked regularly during training (i.e., once every 50 passes over the training set). The training should be stopped when the performance in the validation set starts to increase, despite the fact that the performance in the training set continues to decrease. This method is called *cross validation*. The validation set should be 10% of the training set, and distinct from it. The numbers of iterations were different for Grass Olea and Urticaceae (Tab. 41-49). These values were reached when considering the full pollen season for the mentioned taxa.

9.8.4 Selection of Number of Hidden Layers

The number of input and output nodes corresponds to the number of network inputs and desired outputs, respectively. The choice of the number of hidden layers and the nodes in the hidden layer(s) depends on the network application. Selection of the number of hidden layers is a critical part of designing a network and is not as straightforward as input and output layers. There is no mathematical approach to obtain the optimum number of hidden layers, since such selection is generally falls into the application oriented category. However, the number of hidden layers can be chosen based on the training of the network using various configurations, and selection of the configuration with the fewest number of layers and nodes which still yield the minimum root-mean-squares (RMS) error quickly and efficiently. In general, adding a second hidden layer improves the network's prediction capability due to the nonlinear separability property of the network. However, adding an extra hidden layer commonly yields prediction capabilities similar to those of two-hidden layer networks, but requires longer training times due to the more complex structures. Although using a single hidden layer is sufficient for solving many functional approximation problems, some problems may be easier to solve with a two hidden-layer configuration

.

9.8.5 Normalization of Input and Output Data Sets

Neural networks require that their input and output data be normalized to have the same order of magnitude. Normalization is very critical for some applications. If the input and the output variables are not of the same order of magnitude, some variables may appear to have more significance than they actually do. The training algorithm has to compensate for order-of-magnitude differences by adjusting the network weights, which is not very effective in many of the training algorithms such as the back propagation algorithm. All the pollen data for Grass, Olea and Urticaceae and metereological data were normalised.

9.8.6 Learning Rates

The learning rate is the rate at which ANNs learn depends upon several controllable factors. Obviously, a slower rate means a lot more time is spent in accomplishing the off-line learning to produce an adequately trained system. With the faster learning rates, however, the network may not be able to make the fine discriminations possible with a system that learns more slowly. Researchers are working on producing the best of both worlds [Castellano-Mendez, 2005].

Most learning functions have some provision for a learning rate, or learning constant. Usually this term is positive and between zero and one. If the learning rate is greater than one, it is easy for the learning algorithm to overshoot in correcting the weights, and the network will oscillate. Small values of the learning rate will not correct the current error as quickly, but if small steps are taken in correcting errors, there is a good chance of arriving at the best minimum convergence.

For Grass, Olea and Urticaceae the learning rate was a positive value and was chosen to be 0.75.

9.8.7 Parameterization of NN

The parameterization of the NN was difficult and after using and trying different versions one was chosen between 99-119 neurons as given the best prediction values (tab. 41-49). The parameterization of NN is difficult to calculate as it can lead to an elastic network. In this case it cannot be stated if it determined or selected in the space control area. Those are different from the training one. In both cases the result is not very satisfactory. Different NN were observed and it was seen that the prediction becomes difficult when the neural network is very complex. In the case when the small decay or learning rate is small the prediction values are better.

9.9 RESULTS

For the training period the years used were 1995, 1996, 1998, 2002, 2003 and the year 2004 was used to test the training algorithm network for Grass, Olea and Urticaceae.

The NN model for Olea, Grass and Urticaceae was used for pre-peak, post peak and the whole season. The season has been divided into the pre and post peak in the same way that has been used for the constructing daily forecast with regression methods. The normalized predicted results were converted to the normal one as will be used for daily forecast models.

11.9.1 The prediction model for Olea with neural network in the pre-peak period

The NN model for Olea during the pre-peak period was based on variables such as temperature maximum and rainfall. The variable temperature minimum was excluded from the data set as it was found to be less useful than the other two mentioned variables. The parameterization of NN for the Olea during pre-peak period was chosen to be one with 107 neurons. The architecture of the model was chosen as 3-107-1 (as shown in the tab 41), while three is the input layer with the temperature maximum, rainfall and daily Olea pollen counts and 1 was the output layer that represents the predicted Olea pollen count. The iteration was achieved at 3257 epochs. The coefficient of correlation was 0.96 while the R-squared was 0.92. The value of the learning rate was 0.05 (network complexity). The tested model in 2004 with the NN is shown in the Fig.43.

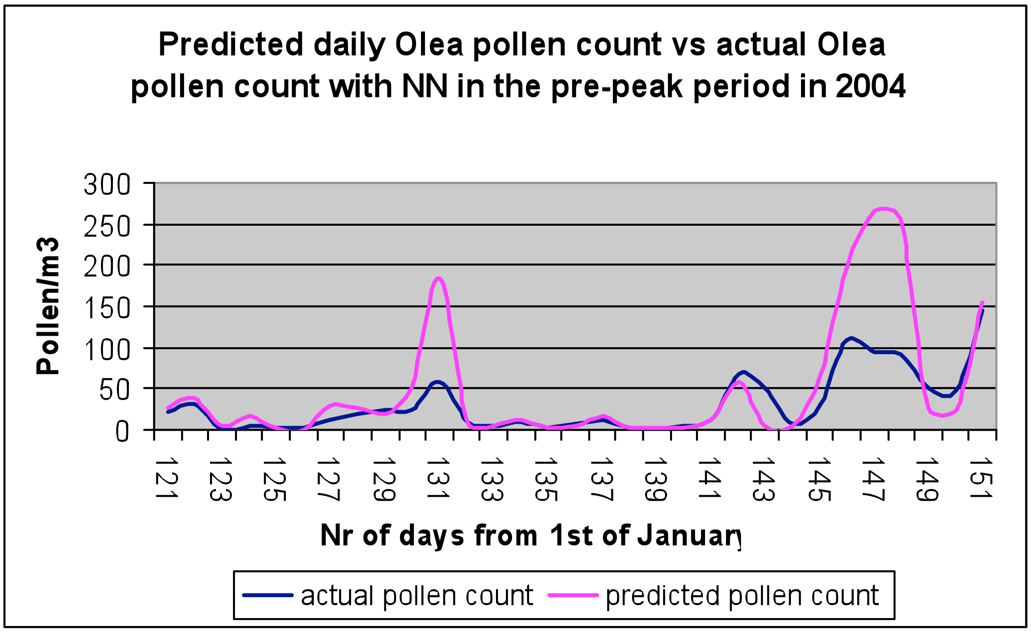


Fig.43 The prediction model for 2004 for daily Olea pollen counts during the pre-peak period with the Neural Network

Tab.41 The outputs of NN for the pre-peak period for Olea

Network error	0,000714
Error improvement	1.14*10^(-7)
Iteration	3257
Training speed	110,0336
Architecture	3-107-1
Training algorithm	Quick propagation
Training stop reason	Desired error achieved
Correlation	0.96

R-squared	0.92

The outputs of Neural Network method for the Olea pollen during the pre-peak period has been shown in Table.41.

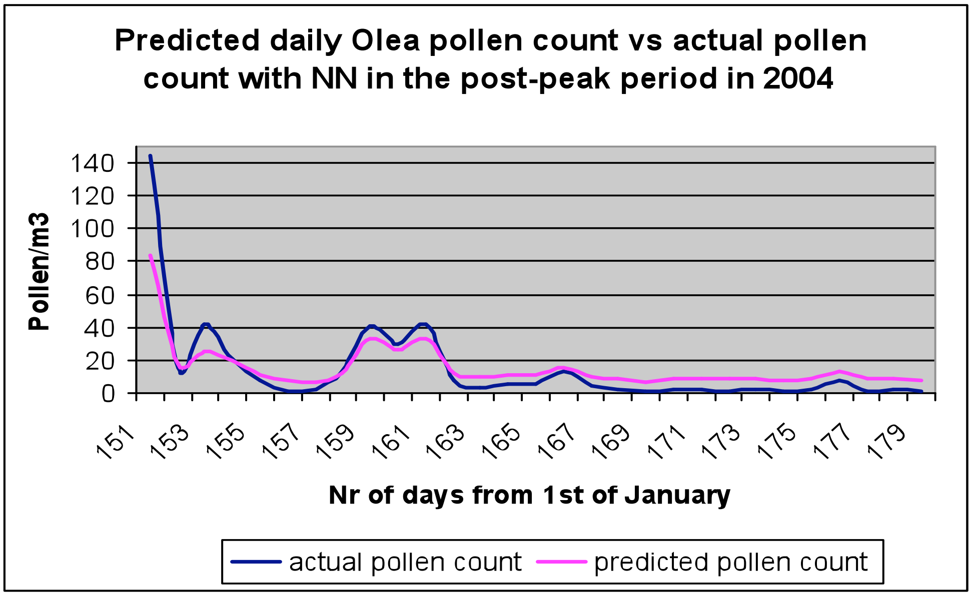
9.9.2 The prediction model for Olea with neural network in the post-peak period

The neural network method for Olea during the post-peak period was based on the same variables as in the model for the pre-peak period. The parameterization of the NN was chosen on with 3-119-1 **(**Table 42). The iteration was 612 epochs. The correlation coefficient was 0.82 while the R-squared was 0.67. The tested model in 2004 for Olea during the post-peak is shown in Fig.44.

Tab. 42 The outputs of NN for the post-peak period for Olea

Network error	0,003496
Error improvement	0,00031
Iteration	612
Training speed	81,89192
Architecture	3-119-1
Training algorithm	Quick propagantion
Training stop reason	Desired error achieved
Correlation	0.82
R-squared	0.67

Fig.44 The prediction model for 2004 for daily Olea pollen counts during the post-peak period with the Neural Network



9.9.3 The prediction model for Olea with neural network for whole pollen season

The neural network method for Olea during the whole pollen season was based on the same variables as in the model for the pre-peak and post-peak period. The parameterization of the NN was chosen with 3-117-1 - tab. 43. The iteration was 11836 epochs. The correlation coefficient was 0.79 while the R-squared was equal with 0.50. The tested model in 2004 for Olea for the whole season is shown in fig. 45.

Tab.43 The outputs of NN for the whole Olea pollen season

R-squared	0.50
Network error	0,002571
Error improvement	5.11*10^(-8)
Iteration	11836
Training speed	42,85325
Architecture	3-117-1
Training algorithm	Quick propagantion
Training stop reason	Desired error achieved
Correlation	0.79

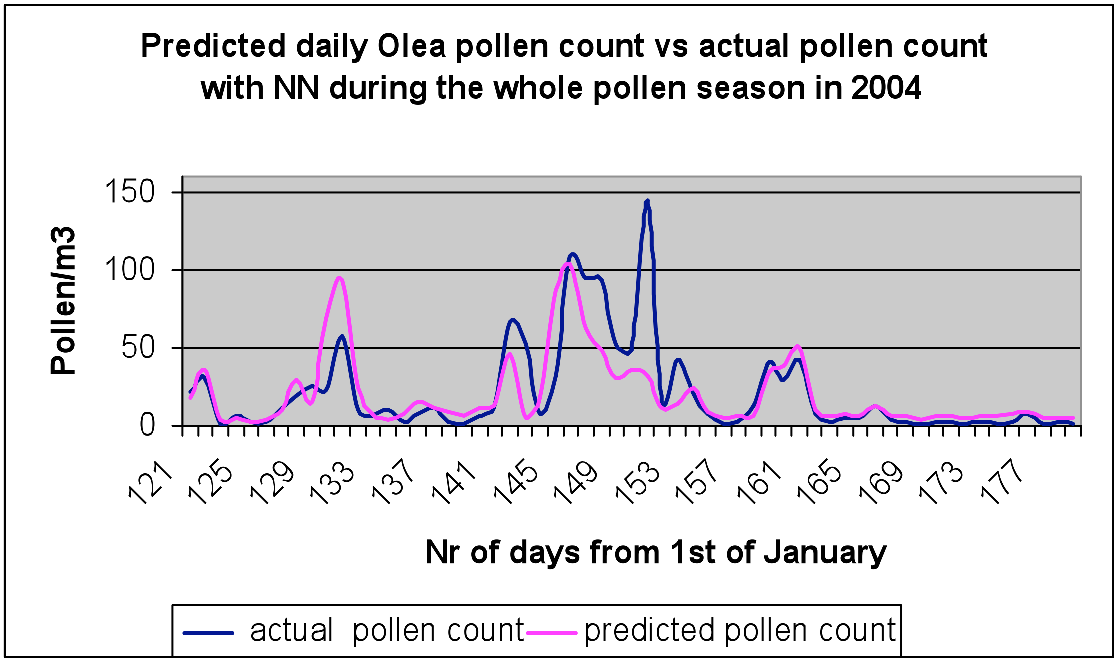


Fig. 45 The prediction model for 2004 for daily Olea pollen counts during the whole pollen season with the Neural Network method

9.9.4 The prediction model for the whole Grass pollen with a neural network

The Grass pollen season was divided into the pre and post peak period with the prepeak period starting from the start of pollen season with the 5% method till the maximum daily values were reached. While the post peak period was defined from the day after the maximum daily values were reached till the end of the pollen season with the 95% method. Also the whole pollen season was used as NN is a very strong model which bases its own work on the principle of learning the curve of the existing form.

9.9.4.1 The prediction model for Grass with neural network in the pre-peak period

The NN model for Grass during the pre-peak period was based on variables such as temperature maximum and rainfall. The variable temperature minimum was excluded from the data set as it was found to be less useful than the other two mentioned variables. The parameterization of NN for the Grass during pre-peak period was chosen with 108 neurons. The architecture of the model was chosen as 3-108-1 (as shown in the table. 44), while three is the input layer with the temperature maximum, rainfall and daily Grass pollen counts and 1 was the output layer that represents the predicted Grass pollen count. The iteration was achieved at 4195 epochs. The coefficient of correlation was 0.97 while the R-squared was 0.62. The value of the learning rate was equal with 0.05 (network complexity). The tested model in 2004 with the NN is shown in the Fig.46.

Tab.44 The outputs of NN for the Grass during the pre-peak period

Network error	0,0026
Error improvement	2.53*10^(-7)
Iteration	7489
Training speed	42,6971
Architecture	3-109-1
Training algorithm	Quick propagantion
Training stop reason	Desired error achieved
Correlation	0.79
R-squared	0.62
Error MSE	0.825

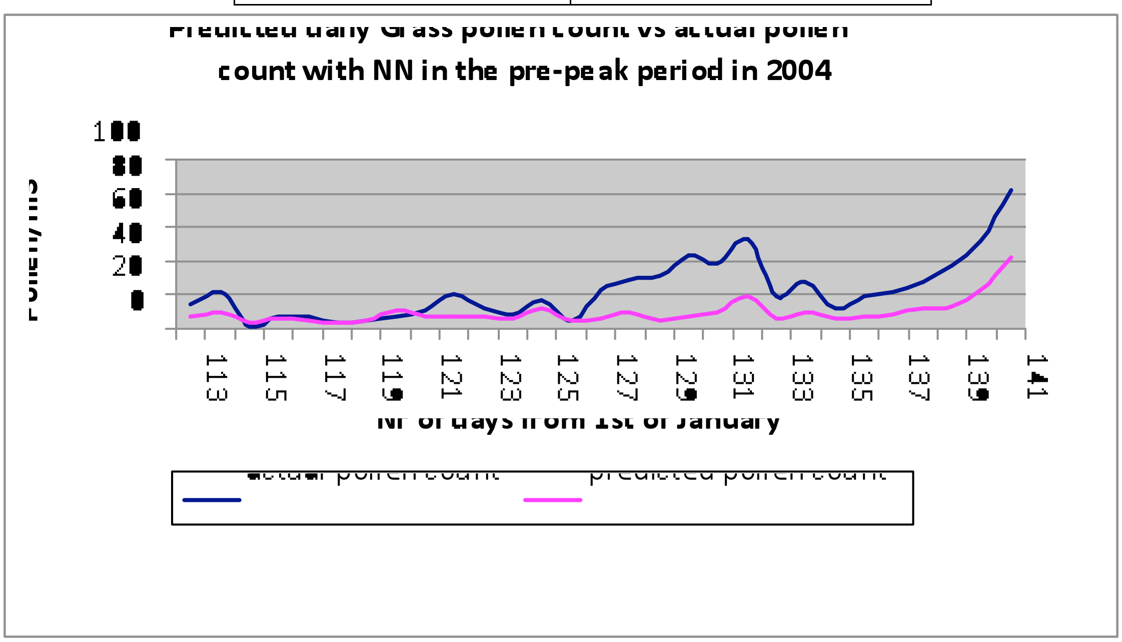


Fig.46 The prediction model for 2004 for daily grass pollen counts during the pre-peak period with the Neural Network method

9.9.5 The prediction model for Grass with neural network in the post-peak period

The neural network method for Grass during the post-peak period was based on the same variables as in the model for the pre-peak period. The parameterization of the NN was chosen on with 3-109-1 (table 45**).** The iteration was 7489 epochs. The correlation coefficient was 0.79 while the R-squared was 0.62. The tested model in 2004 for Grass during the post-peak is shown in Fig.47.

Tab. 45 The outputs of NN for the Grass during the post-peak period

Network error	0,0029
Error improvement	1.09*10^(-7)
Iteration	4195
Training speed	63,3865
Architecture	3-108-1
Training algorithm	Quick propagation
Training stop reason	Desired error achieved
Correlation	0.97
R-squared	0.62
Error MSE	0.86

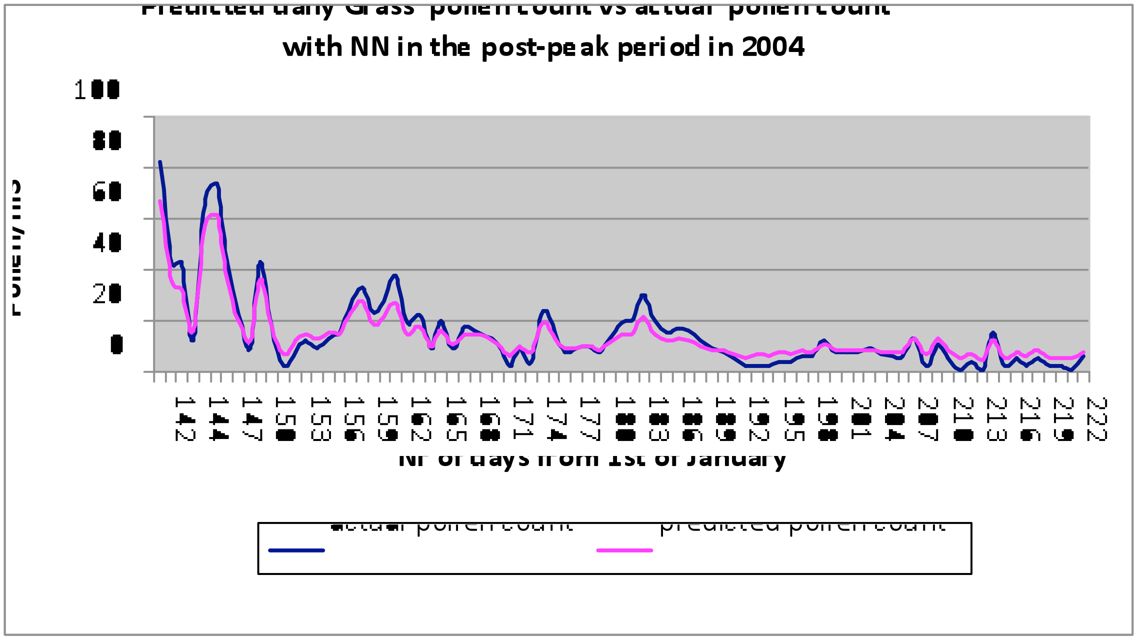


Fig. 47 The prediction model for 2004 for daily grass pollen counts during the post-peak period with the Neural Network method

9.9.6 The prediction model for Grass with neural network in the whole pollen season

The neural network method for Grass during the whole pollen season was based on the same variables as in the model for the pre-peak and post-peak period. The parameterization of the NN was chosen on with 3-109-1 (tab 46). The iteration was 7489 epochs. The correlation coefficient was 0.96 while the R-squared was 0.66. The tested model in 2004 for Grass for the whole season is shown in fig.48.

Tab.46 The outputs of NN for the Grass during the whole pollen season

Network error	0,0026
Error improvement	2.53*10^(-7)
Iteration	7489
Training speed	42,6971
Architecture	3-109-1
Training algorithm	Quick propagantion
Training stop reason	Desired error achieved
Correlation	0.96

R-squared	0.66

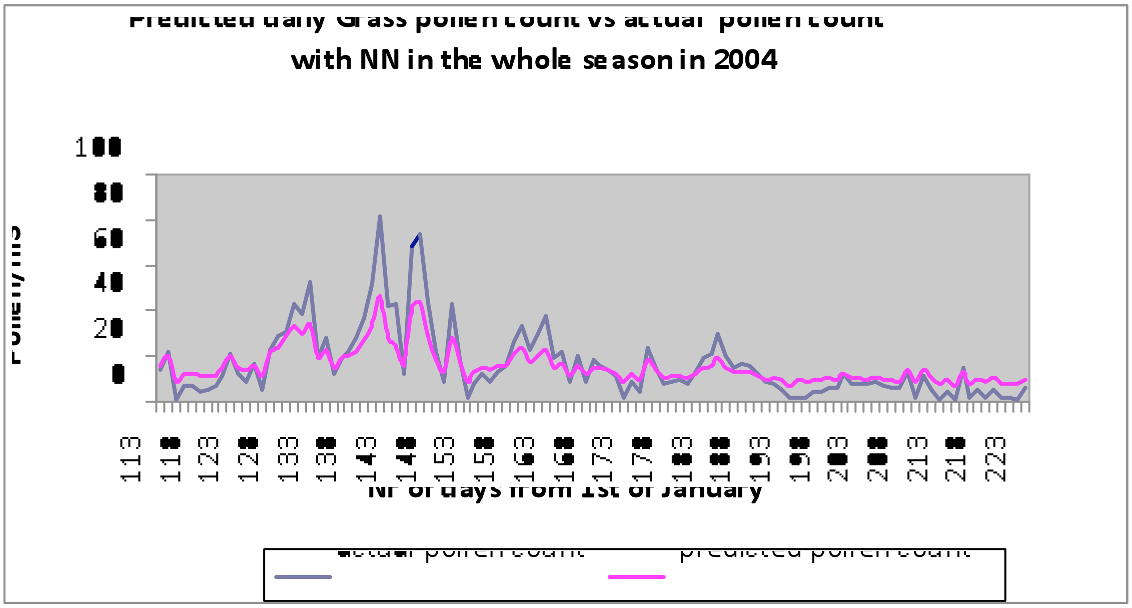


Fig. 48 The prediction model for 2004 for daily grass pollen counts during the whole pollen season with the Neural Network method.

9.9.7 The prediction model for the Urticaceae pollen with a neural network

The attempt to predict the daily Urticaceae pollen count with the use of neural network was based on the same procedure as for Olea and Grass pollen. The data set used was for year 1995,1996,1998,2002 and 2003. The year 2004 was used as a test for the training algorithm network. The normalized predicted results were converted to the normal one as will be used for daily forecast models. Three models were developed for pre and post peak period as well as the whole Urticaceae pollen season. The division of the Urticaceae pollen season into the pre and post peak period has been the same as with grass. The variables that are more dependent on the daily Urticaceae pollen counts were the same as those used for the Grass family respectively as temperature maximum, rainfall and pollen today.

9.9.7 The prediction model for the Urticaceae pollen with a neural network during the pre-peak period

The NN model for Urticaceae during the pre-peak period was based on variables such as temperature maximum and rainfall. The variable temperature minimum was excluded from the data set as it was found to be less useful than other two mentioned variables. The parameterization of NN for the Urticaceae during pre-peak period was chosen with 103 neurons. The architecture of the model was chosen as 3-103-1 (as shown in the table 47**),** while three is the input layer with the temperature maximum, rainfall and daily Urticaceae pollen counts and 1 was the output layer that represents the predicted Urticaceae pollen count. The iteration was achieved at 1221 epochs. The coefficient of correlation was 0.98 while the R-squared was 0.82. The value of the learning rate was 0.05 (network complexity). The tested model in 2004 with the NN is shown in Fig.49.

Tab. 47 The outputs of NN for Urticaceae during the pre-peak period

Network error	0,014139
Error improvement	9.47*10^(-7)
Iteration	1221
Training speed	40,16442
Architecture	3-103-1
Training algorithm	Quick propagation
Training stop reason	Desired error achieved
Correlation	0.98
R-squared	0.82

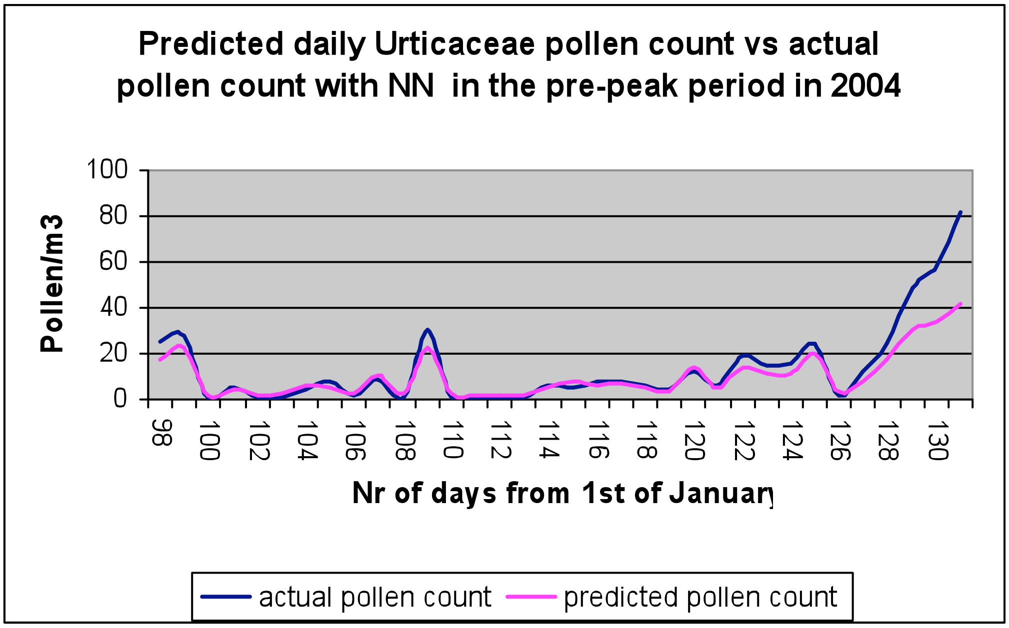


Fig.49 The prediction model for 2004 for daily Urticaceae pollen counts during the pre-peak period with the Neural Network method

9.9.8 Prediction model for the Urticaceae pollen with a neural network during the post-peak period

The neural network method for Urticaceae during the post-peak period was based on the same variables as in the model for the pre-peak period. The parameterization of the NN was chosen on with 3-99-1 (Table 48). The iteration was 2655 epochs. The correlation coefficient was 0.95 while the R-squared was 0.76. The tested model in 2004 for Urticaceae during the post-peak is shown in Fig.50.

Tab.48 The outputs of NN for Urticaceae during the post-peak period

Network error	0,013139
Error improvement	8.08*10^(-7)
Iteration	2655
Training speed	12,02458
Architecture	3-99-1
Training algorithm	Quick propagantion

Training stop reason	Desired error achieved
Correlation	0.95
R-squared	0.76

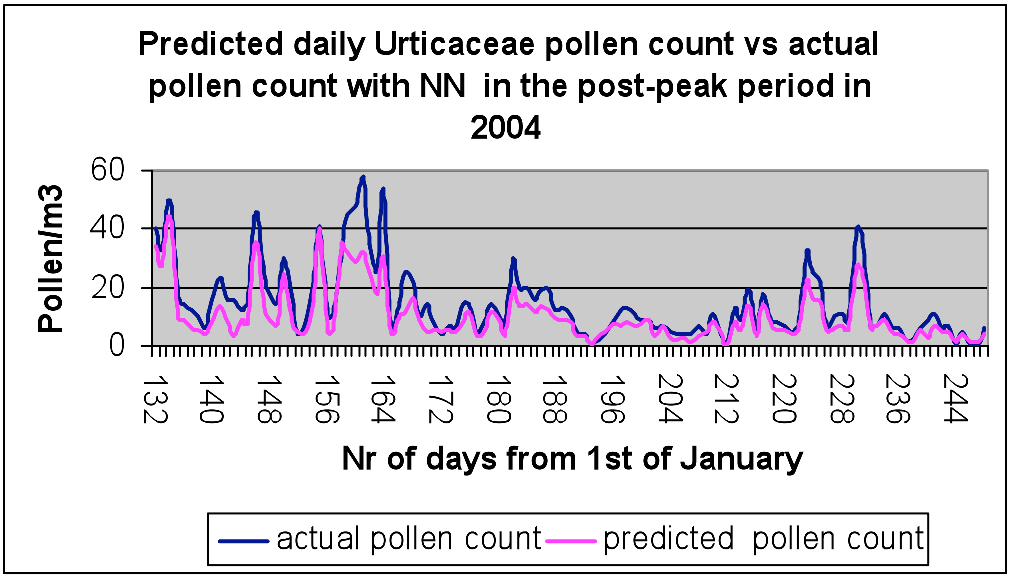


Fig.50. The prediction model for 2004 for daily Urticaceae pollen counts during the post-peak period with the Neural Network method

9.9.9 Prediction model for the Urticaceae pollen with a neural network during the whole pollen season

The neural network method for Urticaceae during the whole pollen season was based on the same variables as in the model for the pre-peak and post-peak period. The parameterization of the NN was chosen with 3-103-1 (Tab 49). The iteration was 429 epochs. The correlation coefficient was 0.97 while the R-squared was 0.85. The tested model in 2004 for Urticaceae for the whole season is shown in fig.51.

Tab.49 The outputs of NN for Urticaceae during the whole pollen season

Network error	0,014657
Error improvement	0,00002

Iteration	429
Training speed	39,72224
Architecture	3-103-1
Training algorithm	Quick propagantion
Training stop reason	Desired error achieved
Correlation	0.97
R-squared	0.85

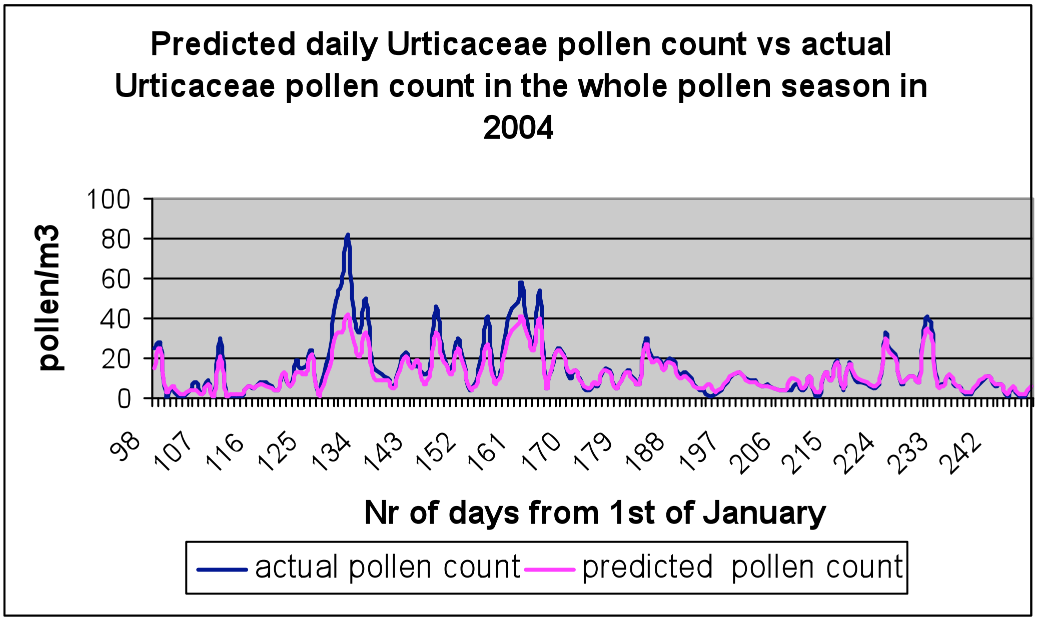


Fig.51 The prediction model for 2004 for daily Urticaceae pollen counts during the whole pollen season with the Neural Network method.

9.9.10 APPRAISAL OF NEURAL NETWORK METHOD

The models used to forecast daily Grass, Olea and Urticaceae with NN achieved satisfactory results. The parameters shown in Tables 41-49, were used to evaluate the accuracy of NN forecast such as coefficient correlation (r) and root mean square (RMSE).

As a conclusion the parameterization optimal of percepton for Grass can be summarised as below (Table 50):

1. a network with 108-109 neurons was used while three neurons in the hidden layer and one in outer layer
2. 0.05 was the value of network complexity (learning rate)
3. a group of variables with Tmax, rainfall and normalised pollen was used
4. The coefficient of correlation and R-squared were higher in the model in the post-peak period.
5. Also the iteration was achived earlier in the pre-peak period with 4195 epochs while for post peak and the whole pollen season was achieved with 7489 epochs.

Grass pollen season	Correlation	R-squared
Pre-peak	0.79	0.62
Post-peak	0.97	0.62
Whole season	0.96	0.66

Tab.50 Correlation coefficient and root mean square for Grass with NN

As a conclusion the parameterization optimal of percepton for Olea can be summarised as below (Table 51):

1. a network with 107-119 neurons was used while three neurons in the hidden layer and one in outer layer
2. 0.05 was the value of network complexity (learning rate)
3. a group of variables with Tmax, rainfall and normalised pollen was used
4. The coefficient of correlation and R-squared were higher at the model in the pre-peak period.
5. The iteration was achived earlier in the post-peak period with 612 epochs while for post peak and the whole pollen season was achieved with 3257 and 11836 epochs respectively.

Tab.51 Correlation coefficient and root mean square for Olea with NN

Olea pollen season	Correlation	R-squared
Pre-peak	0.96	0.92

Post-peak	0.82	0.67
Whole season	0.79	0.50

As a conclusion the parameterization optimal of percepton for Urticaceae can be summarised as below (Table 52):

1. a network with 99-103 neurons was used while three neurons in the hidden layer and one in outer layer
2. 0.05 was the value of network complexity (learning rate)
3. a group of variables with Tmax, rainfall and normalised pollen was used
4. The coefficient of correlation and R-squared were higher in the model in the pre-peak period.
5. The iteration was achieved earlier in the whole pollen season with 429 epochs while for the pre and post peak period was achieved with 1221 and 2655 epochs respectively

Urticaceae pollen season	Correlation	R-squared
Pre-peak	0.98	0.82
Post-peak	0.95	0.76
Whole season	0.97	0.85

Tab.52 Correlation coefficient and root mean square for Urticaceae with NN

CHAPTER TEN- DISCUSSION

10.1 Introduction

The discussion addresses each of the aims and objectives of the thesis and how these have been fulfilled both individually and in relation to each other. The overall conclusions of the thesis are presented in chapter eleven together with an appraisal of the research and a consideration of further work.

In accordance with the title of the thesis certain aims and objectives have been set up in order to achieve the main goal, which is to produce forecast models for the main features of the pollen seasons, and daily average counts for allergenic taxa in central Albania.

The main allergenic taxa chosen for study in the current research were Grass, Olea and Urticaceae. These pollens are also the most allergenic types in the Mediterranean countries as a lot of studies have shown [Frenguelli *et al*., 1989, Diaz de la Guardia *et al*., 1999, D'Amato *et a*l., 1992, 1998].

A study was conducted by the European Community Respiratory Health Survey in Albania [Priftanji *et al*., 1999] during the years 1995 and 1996 to assess the extent of allergic diseases and their important allergens. This work was the first respiratory study in adults carried out in Albania. The subjects were residents in the capital of Albania, Tirana aged between 20-44 years. A questionnaire was filled in by a total number of 2653 subjects. Also a detailed questionnaire was carried out on a random sample of 564 respondents as well as prick tests and serum IgE assay. Amongst the allergens for skin tests were Grass, Olea and Parietaria. The results of skin prick tests showed that this Grass pollen sensitised 10.2% of people followed by 7.6% for Parietaria and Olea.

The findings showed that Grass, Parietaria and Olea were the most important pollen types for allergy although the prevalence of symptoms were low compared with those in other European countries.

This work raised a number of important questions. Among them is why the allergic diseases have a low prevalence in Albania compared with other countries. There are some possible explanations related to the specific circumstances of Albania. The country was isolated till 1990 with no western lifestyle such as the possibility of owning a pet in the house (very few), no private cars and so very few automobile exhaust emissions. In addition travel abroad was not allowed and the rate of smoking was low. However there was high incidence of childhood infection and parasitic infestation. But also Albania had adult death rates that are comparable with those that live in wealthy countries and the diet is rich with lots of fruits and oil olive.

The results of this thesis are discussed in the context of this situation.

10.2 The investigation of the features of the pollen season (timing, severity, length of the season) for the main allergenic taxa in Albania.

In order to fulfill the first aim the data set was normalized to allow direct comparison between seasons [Moseholm *et al*., 1987].

The daily weather data used for the current research were temperature (maximum, minimum) and rainfall obtained from the Meteorological Institute in Tirana. Later on, from the third year of the research it was possible to obtain the wind data (wind direction and wind data) from the Airport of Tirana center which is located 40 km away from the place where the sampler is situated. The wind data did not show significant relationships with the pollen data so this meteorological parameter was discarded from the weather parameters data set used for the research.

Typically for Grass and Urticaceae the pollen season starts with a short period of low counts before the main pollen season start. This normally produces bias to the statistical analysis so this could be excluded by defining the start date by means of a criterion [Mullenders *et al*., 1974, Nilsson *et al*., 1981, Galan *et al*., 2000]. The methods like this have disadvantages as it can be used only after the season has finished but also it had advantages of allowing comparison between seasons. Definitely, the use of thresholds to define the start of the pollen season has more practical value and the future of aerobiology in Albania will help to investigate this issue more deeply.

A lot of methods have been used in order to investigate the features of the pollen seasons for Grass, Olea and Urticaceae. Although various criteria are in use for defining the start and the end of the pollen season, some of them are useful only when there are high airborne pollen concentrations. After carefully studying each of them it was decided to use the 5% method for Grass and Urticaceae which defines the start of the pollen season when 2.5% of the cumulative seasonal catch has been reached and the end of the pollen season when 95% has been reached. This method has been used by many authors [Trigo *et al*., 1996, Pathirane, 1975].

The start of the Olea pollen season was defined with the 1% method as this approach has been used successfully by a lot of authors from Mediterranean countries. This method defines the start of the pollen season as the date on which 1 pollen grain/m3 has been recorded on 5 consecutive days and the end when the count reaches 1 pollen grain/m^3 followed by five consecutive days with the same count or less [Galan *et al*., 2001 a].

A lot of research has been carried out in order to introduce threshold models for the start of the pollen season such as threshold 30 for grass [Davies *et al*., 1973]. Florido *et al*., 1999 reported that a threshold of 400g/m3 is enough to provoke allergic symptoms in subjects clinically sensitive to olive pollen in Spain. In the current research the threshold 30 was inappropriate for Grass pollen counts recorded in the Tirana area. Also the threshold 400 for olive used by Florido is still useless for the Tirana area. It will be necessary to have more clinical data in Tirana city as adopting threshold levels from the countries with similar climate and vegetation seems useless.

A new approach for definining the threshold of most allergenic taxa like Grass, Olea and Urticaceae has been given by Jaeger in the 8th International Conference on Aerobiology in Neuchatel held from 21-15 August, 2006. The approach was based to the calculations that will lead to an approximate threshold value for each pollen type and sampling site. It seems that more work needs to be done on the definition of specific thresholds for allergenic taxa and more advanced ways need to be explored and investigated.

An important outcome of the research work has been the production of the pollen calendar for the main allergenic taxa in Albania. This was not stated as a separate aim but this is the first time such a calendar has been produced. There have been some attempts previously by the author to produce a pollen calendar for Tirana but the data used were based on one or two year's pollen data. The pollen calendar produced in this current research presents a far more representative calendar based on 5 year's data which is the result of monitoring and counting of daily slides by the author. The tables and figures presented in chapter 3 describe four years of data but a fifth year was added for the final production of the calendar. The features of the calendar were not changed by this addition.

10.3 Relationships between pollen data and weather parameters

A lot of studies have shown that the relationship between pollen data and weather parameters are different in pre-peak, peak and post-peak periods [Sanchez Mesa *et al.*, 2003, Toro *et al.*, 1998].

The principal pollen period was divided into three phases (pre-peak, peak and post-peak) for Grass and Urticaceae pollen seasons. In fact the Olea pollination season is very short compared with those of Grass and Urticaceae so it was decided to divide the Olea pollen season into two periods, namely the pre and post peak period. For example, Recio *et al*., 1997 divided the Olea pollen season in two periods, pre-peak and post-peak and identified some environmental factors that influenced to the daily Olea pollen counts during the pre-peak period.

It was decided that the peak period would be defined by the method as shown by Pathirane, 1975, using the graphical curve which eliminates the bias from the low frequency of pollen counts at the beginning and end of the pollen season. The cumulative percentages of the pollen counts were graphically defined allowing the determination of the pollen season to lie between the inflections of the sigmoid curve. The end of peak was considered to be the day when 80% of the total pollen catch pollen has been recorded. This method has been used by Smith & Emberlin, 2005 to define the end of the grass pollen season in the UK. It has been suggested that the use of an arbitrary figure for the end of the pollen season allows more quantitative analysis to be used.

All the details for the division of the pollen seasons have been given in Chapter four-Methodology.

In order to fulfill the aim which was establishing a relationship between the main features of the pollen seasons and the main controlling weather factors a lot of meteorological variables were used in empirical analysis (correlation and regression analysis). This was done in order to investigate which of the weather parameters give most explanation of the features of the pollen season.

A number of variables were examined for the possible inclusion in the linear regression analysis. The meteorological variables were aggregated into monthly and ten, twenty, fifteen days in order to find the best level of explanations. This method is used among the aerobiologists for example in the work of Emberlin *et al*., 1993 a; Jones, 1995, Spieksma *et al*., 1995. The variables that resulted with the highest correlations were included in the constructed models.

Pollen data can be used as a phenological indicator of flowering and many phenological studies using pollen data have been carried out in order to determine the chilling and heat requirements for flowering in various species and geographical areas [Garcia-Mozo *et al*., 2002; Jato *et al*., 2000; Fornaciari *et al*., 2000 ; Galan *et al*., 2001 a].

An attempt to use the phenological methods was made with regards to the start of the Olea pollen season. The use of accumulated growing degree days, thermal sum are in use by different researchers specially those who deal with Mediterranean climates. The attempt was successful when accumulated growing degree days from 1st of March was used. This variable was able to predict the start of the Olea pollen season in a very satisfactory way with 99% accuracy.

10.4 Long term forecasts

It was possible to construct successfully long term forecasts for Grass, Olea and Urticaceae.

The research has made a notable contribution to Aerobiology in Albania by developing models that predict the start, end, length and severity of the pollen seasons for Grass, Olea and Urticaceae. Some attempts were made to forecast the peak date for the mentioned taxa. The preliminary work on relationships between pollen seasons and weather factors which was needed for the long term models for the start of the pollen season for Grass, Olea and Urticaceae showed that the temperature maximum on days that preceded the pollination process influences Grass, Olea and Urticaceae in the Tirana area**.** This reinforces the results found by many researchers that the increase in temperature in the spring does influence the heading times of flowers and the start of the anthesis process before the start of the grass pollen season [Emberlin *et al*., 1993 a, 1999]. Temperature also has been widely accepted as the most important factor affecting processes that lead to the flowering in Olive trees [Orlandi *et al*., 2005].

A lot of authors have reported the significant relationship between the start of Olea pollen season and the temperature recorded during the months prior to the flowering period such as Galan *et al*., 2001 a; Fornaciari *et al*., 1998, Alba and Diaz de la Guardia., 1998.

In all the mentioned studies performed by the authors, the variable mean temperature in February and March was the best variable to predict the start of the Olea pollen season. In Cordoba in particular, the maximum temperature of the first fortnight of March was the best predictor of pollen season onset. This indicates a close relationship with temperatures during the development of the buds produced during the preceding year. In the current research, the variable Tmax mean on days 51-70 (February-Mid March) was the best variable to forecast the start of Olea pollen season.

It is important to note that the location of the pollen trap in Tirana is away from the plantations of Olive so the amounts of Olea pollen should also be dependant on transport as well as the floral phenology and meteorological conditions.

Also an alternative to the forecast model for the start of the Olea pollen season could be the phenological methods which have been proved to predict the start with good accuracy [Galan *et al.,* 2004].

The end of the pollen season for Grass was dependent on the rain on days from 10-20 (January) and Olea seems more dependent on the meteorological April conditions while for Urticaceae it was dependent on the amount of rain in the month of April (days 91-120).

The severity of the grass pollen season was more dependent on the mean of rain at the end of the pollen season (days 121-160) while the severity of the seasons for Olea and Urticaceae was more dependent on the variable temperature in the months that proceed the pollen seasons respectively Tmin on days 51-90 (Feb-March) and Tmax mean on days 91-110 (April). The role of rainfall in the timing and severity of the pollination process is indicated clearly. Enough rainfall for satisfying the water requirements during the month before pollen release allows the plant to complete its development and so influences the pollen production and the earlier pollen release [Laiidi *et al*., 2001, Frenguelli *et al*., 1992]. Recio *et al*., 1996 confirmed also the role of rainfall during the vegetative period of Olea on the pollen production. More biometereological variables like chilling units and evapotranspiration need to be included in the forecast models for Olea. The amounts of pollen produced annually differ depending on climatic conditions also, in the cases of many trees, on inherent reproductive rhythms [Emberlin, 1997]. Many trees have a cyclic rhythm in their pollen production for example the factor known as "Alternance Production" observed with Olive trees [Wheeler, 1992]. This leads to alternating high and low levels of pollen from year to year. In the current research this phenomen was not distinctly observed. Also the changes to the agricultural practices may contribute to the annual pollen counts and severity as in the case of grass pollen counts in Cardiff and Derby [Emberlin *et al*., 1994]. The phenomen of long-range transport of pollen has been also implicated for the severity of Birch pollen [Hjelmroos, 1991].

The length of the grass pollen season was influenced by the Tmax in the first week of February while the Tmin mean in March seems to be important for the length of the Olea pollen season. Hot periods at the onset of flowering favors the release of pollen from anthers and may lead to a shorter pollen season; in contrast release is slower in rainy weather or on days without sunshine, and the pollen season therefore last longer [Corden *et al*., 2002, Clot, 2002, Dopazo *et al*., 2001].

The start peak model for Grass and Olea was forecast through using the rain mean in the first two weeks of March. The model to forecast the peak date for Urticaceae was difficult to construct due to the characteristic features which the Urticaceae pollen curve possesses. More focused work is needed on the investigation of the environmental factors that contribute to the peak date values.

10.5 Short- term models

The third aim is related to the building of short term forecast models for selected pollen types in Albania.

The models were constructed through using receptor-orientated models which have been proved to be powerful in aerobiology studies [Emberlin *et al*., 1999, Norris-Hill *et al,* 1995]. The receptor orientated models do not necessarily need the information or knowledge of source conditions so they are more dependent on the relationship between pollen counts and variables that could be predicted [Norris-Hill, 1995]. But these models are empirical so a theory or rationale is necessary to determinate the strength and direction of the relationships that do exist between dependent and independent variables. This information facilitates the process of choosing the right independent variable to be included in the model [Norris-Hill, 1995].

The regression analysis has been used to produce short term forecasts for Olea, Grass and Urticaceae. Multiple regression is just not one technique but a family of techniques that can be used to investigate the relationship between dependent and independent variables [Pallant, 2001]. Multiple regression is based on correlation although it allows a more sophisticated exploration of the interrelationship among various variables. The use of the correlation analysis in the research helped toward the better understanding of factors that affect the release, dispersal and pollen production for the taxa mentioned.

Almost all aerobiological forecasting tools are evaluated at some stage at their development. First, correlation coefficients between aerobiological data and environmental (most meteorological) variables are used to find out the most relevant factors to explain the airborne particle concentrations, then a subsequent detailed regression analysis is performed and the resulting algebraic equation allows the establishment of a quantitative forecast model and its associated errors [Barrera *et al*., 2002].

Three different models have been developed for Grass and Urticaceae using regression analysis but only two for Olea. In the case of Olea as it has been explained earlier the pollen season was divided into two periods so two models for pre and post peak have been produced.

For Grass it seems that Temperature maximum and the pollen concentrations of the two previous days are the most useful variables to use to build a forecast for the pre-peak period. While for the peak and post peak period temperature minimum was a better predictor. It seems that the use of the pollen concentrations of previous days (1-5 days) helped the model to be robust. The use of such parameters to develop short term models has been used by other researchers. For instance Galan *et al*., (2000), reported that the highest correlation between Urticaceae pollen concentration and meteorological parameters was achieved during the non-rainy season.

Correlation analysis has shown that the release and dispersal of pollen from the plant is highly reliant on weather that can change as the season progress [Mesa *et al*., 2005]. The summers in Tirana are very hot and temperature maximum can exceed 36^{o}C which makes the correlations between grass pollen counts and meteorological parameters weaker and can even cause inverse relationships.

The significant correlation coefficients were achieved between Olive pollen counts and the concentrations of five- previous days during the pre-peak period. However the dispersion of the olive pollen in the air depended not only on the intrinsic factors but also on the extrinsic ones such as meteorological factors. The correlation obtained for the pre-peak period of Olea pollen suggests that temperature increases the amount of olive pollen as it promotes pollen emission by favoring dehydration and dehiscence of the anthers as well as acting on dispersion by transporting the particles on thermal currents. In the opposite way, humidity and rainfall usually correlates negatively with the amount of pollen in the air by provoking aggregation and deposition of pollen.

In the models produced, the Temperature maximum, temperature minimum and pollen concentration of previous days were the best variable to predict the daily Urticaceae pollen counts. Previous studies have confirmed that Urticaceae pollen counts are influenced in particular by maximum daily temperature [Galan *et al*., 2000, Laaidi, 2001, Dvorin *et al*., 2001]. Such studies demonstrated that a statistical correlation exists between maximum daily temperature and Urticaceae pollen concentration [Galan *et al*., 2000]. These studies have also suggested that among the temperature, a significant increase in diurnal temperature range encourages Urticaceae maximum pollen concentrations as well as the lack of rainfall. More work needs to be done in future to investigate the diurnal temperature influence on the daily Urticaceae pollen counts.

Galan *et al*., 2000, used the pollen concentration of the previous day or the two previous days as an independent variable to forecast daily Urticaceae pollen counts. The authors reported that these were important variables to predict the daily Urticaceae pollen counts in the air when rainfall failed to produce the desired washing effect.

An attempt was made to develop a short term forecast for the non-rainy days for all the mentioned taxa. It has been shown that rainfall exerts a strong influence on the daily forecast models sometimes causing distortion in the strength of the forecast [Fornaciari *et al*., 1992]. The results achieved by regression models were satisfactory for Grass and Urticaceae during the pre and peak period and for Olea during the post-peak period. It should be noted that the small data set sometimes does not give the right indication about different relationships between independent and dependent variables hiding or overestimating them. The accuracy of models increases when the constructed models can be tested in more than one year as the features of the year (normal or extreme) can be very different. This is the reason why the forecast models were tested in two years. The weather forecast available in Albania covers the prediction of temperature (maximum, minimum) and rainfall. These factors can be used routinely in the models that have been constructed. The constructed models will contribute to public health information for a large number of people allowing for the first time an Aerobiology forecast models to be used in Albania similar to those in other countries.

The use of correlation and regression analysis helped to provide a better understanding of the factors that influence the dispersal, transport and production and release of pollen through the season. It is well known that daily pollen concentrations for most allergenic taxa are related to those factors. The lack of other meteorological parameters such as humidity, wind and turbulence in routine weather reports precludes their use in practical models. Similarly the lack of information about pollen settling factors and deposition means that these cannot be incorporated into practical use. Further work needs to be done on this kind of information before sophisticated multivariate models can be developed.

In this research the performance of Neural Network (NN) methods was explored to develop short term forecasts for grass, Olea and Urticaceae. The achieved results showed very good performance of the model when the correlation coefficient and R-squared were considered. The models developed were able to forecast the daily pollen counts for grass, Olea and Urticaceae either divided in two periods such as pre and post peak or as a whole pollen season. The use of NN model forecasting for the whole pollen season gives the advantage of operating the system easily with the need of mathematicians. The temperature maximum and rainfall were used as variables in forecasting model for the mentioned taxa.

However, the introduction of more meteorological variables such as humidity and wind speed in combination with pollen data needs to be explored in order to allow the improvement of forecast accuracy.

The good performance of NN is linked to its structural and functional characteristics such as the nonlinear model capability and the universal function of approximation [Arca *et al.,* 2004]. The mentioned characteristics can be used to allow the NN models to be used as a tool to forecast the pollen concentration and to support the preventive allergic therapy. In the same was other statistical models, the NN models require local calibration to produce reliable results

The forecast models (short and long term one) will be for use by the public, doctors etc. They also are available in the media through newspapers, through the weather forecast etc.

The models used for the characteristics of the pollen season like start, peak and end can be used retrospectively or at the time the pollen season has started. However, the developed models help in the understanding of the factors that influence the time of the pollen season and their abundance. However, there is still no consensus among aerobiologists about which thresholds should be used for the start of the pollen season for some allergenic species. The threshold used by many authors for Grass (30 threshold) and Olea (400- threshold) were tried in the current research but were not suitable to be used in these models.

In the future a longer pollen data set for Albania will help to realize some other models that predict the characteristics of the pollen season in the prospective way.
The daily pollen forecast will be reported to the public as a scale from 1-10 indicating the risk index in the same way as other European countries do. The daily forecast will start each year as soon as the season begins for Grass, Olea and Urticaceae. The daily meteorological data will be obtained from the Meteorological Institute in Tirana and the data will be used for the forecasting models.

The models were tested in the years 2003 and 2004. As the research was carried out from 2003 onwards and the student is in charge of the pollen monitoring system in Albania, it was not possible to include the data set from the year 2005 and 2006. The skills gained through using the proper methodology in the pollen forecast models will allow the extension of the work and the updating pollen forecast models for Olea, Grass and Urticaceae.

10.6 Aerobiology as a scientific discipline in Albania

Among the objectives of the research is the establishment of Aerobiology as a scientific discipline in Albania. Aerobiology is a scientific discipline that covers many aspects of airborne particles and spores. It seems that the use of the models developed to predict the start and end of the season, its length and severity for the most allergenic species will help also in providing useful information to assist in the diagnosis of allergic diseases and improvement of their management which is the second objective of the research.

The longer data set on pollen data, the possibility of comparing those data with meteorological parameters, the establishing of short and long term forecasts for the main allergenic taxa such as Grass, Olea and Urticaceae will also contribute to the establishment of a data base for pollen counts for use in agriculture and related disciplines. This is the third objective of the research. The potential to achieve this is now in place. It should be noted that the achievement of such objectives is not a process that requires only three and four years of research. The results of this current research will strengthen the body of knowledge leading towards the fulfillment all the objectives mentioned. Albania is a country with a Mediterranean climate and its neighbors such as Italy, Greece and Yugoslavia have established Aerobiology as a scientific discipline to various extents already both practically and for use in different research purposes. Aerobiology in Albania will help to foster collaboration with those countries. In recent years a lot of joint research projects on phenomena in Aerobiology such as long-distance transport of pollen have been set up through such collaboration with similar countries.

Also the contribution of Aerobiology of Albania to the EAN/EPI exists already but expanding the aerobiology network will give better coverage. More aerobiologists need to be trained in Albania and the skills developed through this research will help to contribute expertise to the aerobiologists trained. Currently at the University of Natural Sciences in Tirana there is not any course or module that offers or covers topics in Aerobiology. The results of this thesis will be the basis for future development of Aerobiology in Albania.

CHAPTER ELEVEN: CONCLUSIONS

11.1 Introduction

This chapter presents the main conclusions of the research work in relation to the aims and objectives of the study. For clarification these are listed as a number of points. The conclusions are followed by an appraisal of the work and a discussion of possible future research on this topic.

11.2 Main conclusions

- A pollen calendar for Tirana has been produced for the first time in Albania based on five years of data. The main important allergenic taxa have been studied in relation to their occurrence and abundance through the twelve months of the year.
- Significant relationships were found between certain characteristics of the Poaceae, Olea and Urticaceae pollen seasons and Temperature maximum, Temperature minimum and rainfall in Tirana during the four years of study.

<u>Grass pollen Season</u>

- The most important variables for the main pollen season of grass were: Tmax and Tmin in the days between 1-90 starting from the 1st of January. The significant correlations showed negative relationships when the temperature variables were used in the Pearson correlation. The best variable chosen to explain the start of Poaceae pollen season was Tmax in days 61-70 from 1st of January.
- The significant relationships for the end of the grass pollen season were linked to the rain variables with different combinations from 1-120 days from 1st of January. The variable rain in days 11-20 was chosen to use in the linear regression to predict the end date of the Grass pollen season.

- Severity of the grass pollen season is linked to the variable rain in days 121-160 with a negative relationship. No more variables were found that contributed significantly to the explanation of the severity of the grass pollen season.
- The meteorological variable that showed significant positive correlation with the length of the grass pollen season was the variable Tmax mean on days 41-50 from 1st of January.
- The start of peak period for the grass was linked with the variable rain mean on days 1-50 while the end of peak period was linked with the variable Temp min mean on days 1-20.
- The start day of peak count for grass was linked with the variable rain mean on days 61-80.

<u>Olea Pollen Season</u>

- The variables rain and the Tmax and Tmin between the periods of 1-70 days starting from 1st January were the best variables to explain the start of the Olea pollen season. The mean of Tmax in days 51-70 was chosen as the best variable to enter in the linear regression model.
- The variable Tmax mean in days 91-120 was chosen as the best variable to explain the end of the Olea pollen season.
- The variable Tmin mean on days 51-90 was the best parameter to explain the severity of the Olea pollen season. The other variables that showed positive relationships with the severity of the Olea pollen season were combinations of Tmin in days 31-90 days from 1st of January.
- Tmin mean on days 51-90 from 1st of January was the variable that gave the best explanation for the length of the Olea pollen season. Other variables that showed significant relationships with the length of the Olea pollen season were rain days on days 21-30 and Tmin in days 10-30.
- The variable rain mean on days 61-80 was used to predict the start day of peak count for Olea.
- The variable accumulated growing degree-days from 1st of March was used to predict the start of Olea pollen season. It achieved a 97% accuracy in 2003 and 86.6% in 2004. The variable accumulated temp max from 1st of January was used

to predict the start date of Olea pollen season. The accuracy achieved was 98% in 2003 and 81.5% in 2004.

Urticaceae pollen Season

- The variable rain and Tmax with different combinations from days 1-70 from 1st of January were the variables that showed significant relationships with the start of the Urticaceae. After careful consideration Tmax mean on days 1-30 was chosen as the most appropriate variable to enter in the linear regression model.
- The variables rain and Tmin mean on days 51-90 from 1st of January were the best variables that showed significant relationships with the severity of the Urticaceae pollen season. Tmax mean on days 91-110 from 1st of January was chosen as the best variable to enter into the linear regression model.
- Rain and Tmin mean with different combinations on days from 40-100 from 1st January were the variables that were able to give the best explanation of the length of the Urticaceae pollen season. The variable rain amount on days 61-90 from 1st of January gave the best explanation for the model of linear regression.
- The variables rain and Tmax from days 40-120 with different combinations showed significant correlations with the end of the Urticaceae pollen season. The variable rain amount on days 91-120 was the best variable to explain the end of the Urticaceae pollen season which was entered in the linear regression model.
- Further attempts were made to use the wind direction and wind speed data in the forecast models. The analyses performed by Kruskal Wallis tests concluded that these variables did not make any contributions to the variation in daily pollen counts for the mentioned taxa.

Grass Pollen season Long Term models

- The long term forecast models were constructed for the start, end, length, peak date, end of the peak period and severity for the grass pollen season. The start of the grass pollen season was considered to be the day when 5% of the total cumulative of grass pollen was achieved. The end of the grass pollen season was considered to be the day when 95% of the total cumulative pollen grass was reached. The start of peak period was considered through the method of Pathirane [1975], while the end of the peak period was considered to be the date when 80% of the total cumulative pollen catches has been reached.

- The models used for the forecast of the grass main pollen season achieved success. The temperature maximum on the days 61-70, was the best variable to predict the start of the grass pollen season. When the model was tested on the data for 2003, the actual start of the grass pollen season was predicted with only three days difference and with eighteen days difference in 2004. It could be concluded that the accuracy for this model was equal to 98% for 2003 and 86% % in 2004.
- The best predictor to be used in the models to predict the end of the grass pollen season was rainfall on days 11-20. The predicted model enabled the end date of the grass pollen season to be forecast with 88.8% accuracy in both years 2003 and 2004 when the 95% method was used.
- The predictor that was able to forecast the severity of grass pollen season was rain days on days 121-160. The accuracy achieved was equal to 81% in 2003 and 74% in 2004.
- The temperature maximum on days 41-50 was the best predictor to forecast the length of the grass pollen season. The achieved accuracy was equal to 77% in 2003 and 48% in 2004.
- The rain mean on days 61-80 was the best parameter to forecast the start of the peak count for grass pollen. The accuracy achieved was equal to 98.5% in 2003 and 97.8% in 2004.
- The Temperature minimum on days 1-20 was the best predictor to forecast the end of the peak period for grass pollen. When tested on data for the year 2003 the accuracy achieved was equal to 89.2% and 61% in 2004.
- The variable temp min mean on days 1-50 was able to predict the start day of peak period for grass. The accuracy achieved in 2003 was 97% and 99% in 2004.

Daily Forecast Models for grass pollen including the models on non-rainy days

- Three different multiple regression models were used to predict the daily grass pollen counts in Tirana during pre-peak, peak and post-peak periods. The predicted and actual daily grass pollen counts were converted into numerical scores. The percent accuracy for each model has been evaluated and reported. Also the predicted and actual grass pollen counts were compared through correlation analysis to evaluate the curve of the prediction daily grass pollen for each period. All the models except the model for the post-peak period were able to predict the trend of the grass pollen counts.
- A multiple regression model was able to forecast the daily variation of grass pollen counts during the pre-peak period. The pre-peak period was considered to be the period between the start of the grass pollen season until the maximum grass pollen counts were recorded with the pollen sampler. The temperature maximum and the pollen counts of two previous days were the best parameters to predict the daily grass pollen counts during the pre-peak period. The percent accuracy obtained was equal to 69% when the model was tested on data for 2003 and 29% in 2004.
- A multiple regression model was used to predict the daily grass pollen counts during the peak period. The peak period was considered to be the period from the date when the maximum grass pollen counts were recorded with the pollen sampler till the 80% value of the cumulative daily pollen counts was reached. The variables used to forecast the daily grass pollen counts in the peak period were temperature minimum and the grass pollen counts of five previous days. The obtained percent accuracy was equal to 90% in 2003 and 68% in 2004.
- A multiple regression model was constructed for the daily pollen counts during the post-peak period in Tirana. The variables used were temperature minimum and the daily grass pollen counts of two previous days. The accuracy achieved was 65% in 2003 and 87% in 2004.
- A multiple regression model was used to predict the daily grass pollen counts in the pre-peak period on the non-rainy days. The variables Tmin and the grass

pollen count of two previous days were used as predictors. The accuracy achieved in 2004 was 70% with an increase of 41% compared with the models that included the rainy days.

- A multiple regression model was used to predict the daily grass pollen counts in the peak period on the non-rainy days. The temperature minimum and the pollen counts of five previous days were the best parameters to predict the daily grass pollen counts during the peak period on the non-rainy days. The accuracy achieved in 2004 was 69%. It increased with 1% the accuracy when compared with the model that did include the rainy days and decrease with 18% in 2003 with the same comparison.
- A linear regression model was used to predict the daily grass pollen counts in the post- peak period on the non-rainy days. The pollen counts of five previous days were the best parameters to predict the daily grass pollen counts during the post-peak period on the non-rainy days. It achieved an accuracy of 65% in 2003 and 87% in 2004. The same accuracy for both years was achieved with the models that did include the rainy days.

<u>Long Term forecast models for Olea pollen</u>

- Various metereological variables were considered in the correlation analysis performed for the evaluation of the Olea pollen season. The variables that gave the highest correlation were entered into the model. Due to the small sample size linear regression was used rather than multiple regression to build long-term forecasts for the Olea pollen season.
- The start of Olea pollen season was considered to be the day when 1 pollen/m3 daily average was recorded in the air followed by subsequent days with 1 or more pollen/m^3. The end of the Olea pollen season was considered the day when 1 pollen/m^3 daily average was found followed by at least three days with no Olea pollen grains detected in the air. The determination of the start day of the peak count was the same as for grass pollen. The simple linear regression model to predict the start of Olea pollen season used as the predictor the temperature maximum mean on days 51-70. The accuracy achieved was equal to 99.2% when

the model was tested in year 2003 and 85.8% in 2004. Other attempts have been made to predict the start of Olea pollen season through using phenological methods. Different variables have been studied such as accumulated temperature from 1st of January, accumulated growing degree days and thermal sum. The variable growing degree days gave the best percent accuracy when the model was tested in year 2003 with 97% and 86% accuracy in 2004.

- The variable used to predict the end of the Olea pollen season was temperature maximum mean on days 91-120 starting from 1st of January using the simple linear regression. The obtained accuracy was 97.5% in 2003 and 39 % in 2004.
- The simple linear regression model was used to forecast for the severity of the Olea pollen season using the temperature minimum mean on days 51-90. The predicted model enabled the severity of Olea pollen season to be forecast with an accuracy of 84.4% in 2003 and 60% in 2004.
- The temperature minimum mean on days 51-90 was the best predictor to forecast the length of the Olea pollen season using the simple linear regression. The obtained accuracy was equal to 68.7% in 2003 and 82.7% in 2004.
- The variable used to predict the start day of the peak count for Olea was rain mean on days 61-80. The predicted model enabled the prediction of the start day of the peak count with 98% accuracy in 2003 and 96.6% in 2004.

Daily Forecast models for Olea pollen including the models on non-rainy days

- Two multiple regression models were built to forecast the daily Olea pollen counts for the pre and post peak period. The reason why only two multiple regression were constructed was related to the fact that it was a small sample size and it could be not divided into three periods. The peak period was considered to be the period from the start of Olea pollen season till the maximum Olea pollen counts were recorded with the pollen sampler. The post-peak period was considered to be the period from the day when the maximum Olea pollen counts were recorded till the end of the Olea pollen season.

- Temperature maximum and the Olea pollen counts of five previous days were the best variables to be used to forecast the daily Olea pollen counts during the pre-peak period. The percent accuracy was 42% when the model was tested on data for the year 2003 and 57% in 2004.
- A multiple regression model was used to predict the daily Olea pollen counts in the post-peak period. The variables Tmax and the Olea pollen count of four previous days were used as predictors. The accuracy achieved in 2003 was 57% and 82% in 2004.
- A multiple regression model was used to predict the daily Olea pollen counts in the pre- peak period on the non-rainy days. The temperature minimum and the pollen counts of five previous days were the best parameters to predict the daily Olea pollen counts during the pre- peak period on the non-rainy days. The accuracy achieved in 2004 was 60%. It increased with 13% the accuracy when compared with the model that did included the rainy days for the same year. There was no rainfall recorded during the pre-peak period in 2003.
- A multiple regression model was used to predict the daily Olea pollen counts in the post- peak period on the non-rainy days. The pollen counts of five and two previous days were the best parameters to predict the daily Olea pollen counts during the post- peak period on the non-rainy days. It achieved an accuracy of 65% in 2003 and 36% in 2004. It showed the same accuracy when compared with the model that included the rainy days in 2003 and decreased the accuracy with 53% in 2004.

Long Term Forecast models for Urticaceae

- A lot of meteorological variables were considered for use in the correlation analysis to investigate the characteristics of the Urticaceae pollen season. The meteorological variables with the highest correlation were entered into the correlation analysis. Different linear regressions were used to build long term forecast models for Urticaceae pollen. As a result the main characteristics of the Urticaceae pollen season have been investigated and studied. The start of

Urticaceae pollen season was considered to be the day when 5% of the daily cumulative values have been reached. The end of Urticaceae pollen season was considered to be the day when 95% of the cumulative values have also been reached. The start of and end of the peak period has been defined in the same way that Grass and Olea has been defined.

- Temperature maximum mean on days 1-30 was the best predictor to enable the simple linear regression to forecast the start of Urticaceae pollen season. The obtained accuracy was equal to 94% when the model was tested on data for the year 2003 and 72% in 2004.
- The amount of rainfall on days 91-120 enabled the construction of a simple linear regression model for the end of the Urticaceae pollen season. The accuracy achieved was 99% in 2003 and 81% in 2004.
- The severity of the Urticaceae pollen season was investigated through the use of a linear regression model. The model used as the predictor the mean of temperature maximum on days 91-110. The prediction model enabled the severity of the Urticaceae pollen season to be forecast with 96% accuracy in 2003 and 41% in 2004.
- A simple linear regression was performed to forecast the length of the Urticaceae pollen season. The variable total rainfall on days 61-90 was able to predict the length of Urticaceae pollen season with 84% accuracy in 2003 and 93% in 2004.
- The variable used to predict the start day of the peak count for Urticaceae was rain mean on days 11-20. The predicted model enabled the prediction of the start of the peak count with 98% accuracy in 2003 and 87% in 2004.
- The rain mean on days 61-80 was the best meteorological predictor for the end date of Urticaceae peak period using a simple linear regression. The obtained accuracy was 94.4% in 2003 and 34 % in 2004.

Daily Forecast models for Urticaceae pollen including the models on non-rainy days

- Three multiple regressions were used to predict the daily Urticaceae pollen counts during the pre, peak and post peak period.
- The variables temperature maximum and the pollen counts of three previous days enabled the prediction of the Urticaceae pollen counts during the pre-peak period. The accuracy achieved was 90% in 2003 and 89% in 2004.
- A multiple regression model was used to predict the daily Urticaceae pollen counts during the peak period. The variables used for this model were temperature minimum and the Urticaceae pollen counts of two previous days. The accuracy achieved with the model was 90% in 2003 and 79% in 2004.
- A multiple regression model was used to predict the daily Urticaceae pollen counts during the post- peak period. The variables used for this model were temperature minimum and the Urticaceae pollen counts of three previous days. The accuracy achieved with the model was 65% in 2003 and 67% in 2004.
- A multiple regression model was used to predict the daily Urticaceae pollen counts in the pre- peak period on the non-rainy days. The pollen counts of three and four previous days were the best parameters to predict the daily Urticaceae pollen counts during the pre- peak period on the non-rainy days. The accuracy achieved in 2003 was 90% and 91% in 2004. It increased with 2% the accuracy when compared with the model that did included the rainy days for 2004.
- A multiple regression model was used to predict the daily Urticaceae pollen counts in the peak period on the non-rainy days. The temperature minimum and the pollen counts of two previous days were the best parameters to predict the daily Urticaceae pollen counts during the peak period on the non-rainy days. It achieved an accuracy of 85% in 2003 and 89% in 2004. It increased the accuracy with 10% when compared with the model that included the rainy days in 2004 and decreased with 5% in 2003.

Neural Network Models

- Neural network (NN) models have been used for forecasting daily pollen counts for Grass, Olea and Urticaceae. The constructed models were able to forecast the daily pollen counts for Grass, Olea and Urticaceae. The pollen season for the mentioned taxa was entered in the model as a complete season as well as pre and post peak periods. The pre-peak period was considered to be the period when 5% of the cumulative pollen counts have been achieved till the maximum pollen count. The post-peak period was considered to be the period from the day when the maximum pollen counts were achieved till the 95% of the achieved cumulative values. The model that considers the pollen season was a whole has the advantage of giving an easier operation of the model.

Neural netwok model for grass

- A network with 108-109 neurons was used while three neurons were used in the hidden layer and one in the outer layer
- A group of variables with Tmax, rainfall and normalized pollen were used
- The model with NN for grass gave higher correlation coefficient during the post peak and as a whole pollen season. The correlation coefficient for the pre-peak period was 79% while for the post-peak period was 97%. The correlation coefficient for the whole grass pollen season was 96%. The R- squared was higher in the model for the post-peak period.

Neural netwok model for Olea

- A network with 107-119 neurons was used while three neurons were used in the hidden layer and one in the outer layer.
- A group of variables with Tmax, rainfall and normalized pollen were used
- The model with NN for grass gave higher correlation coefficient during the pre and post peak period with a correlation coefficient of 96% and 82% respectively while for the whole pollen season was 79%. The R- squared was higher in the model that consider the whole pollen season.

Neural netwok model for Urticaceae

- A network with 99-103 neurons was used while three neurons were used in the hidden layer and one in the outer layer.
- A group of variables with Tmax, rainfall and normalized pollen were used
- The model with NN for grass gave higher correlation coefficients during the pre and post peak period with a correlation coefficient of 98% and 95% respectively while for the whole pollen season was 97%. The R- squared was higher in the model that consider the whole pollen season.

11.3 The importance of the conclusions

The main important outcomes of the research are related to the construction of forecast models to predict the features of the main pollen seasons of Olea, Grass and Urticaceae and also their daily variations.

These models were developed specifically for the Tirana region but the expertise gained in their construction can be applied to other areas of Albania.

The results illustrate the fact that forecast models need to be developed for specific locations due to the differences in local conditions including topography, vegetation and climate. The general methodology is transferable but the specific relationships between variables need to be investigated for different locations. The research for this thesis has not only produced models for specific use in central Albania, but it has also contributed to the body of knowledge in Aerobiology generally. This is particularly the case in the development of the methodology for neural networks. The thesis, therefore, has importance not only for Albania but also for the international science of Aerobiology.

11.4 APPRAISAL OF THE WORK

All the aims and objectives of the research work have been fulfilled as discussed previously in this chapter.

As it has been mentioned during this research work, this study is the first one to be conducted in Albania in this field. Aerobiology is a new scientific discipline in Albania. Its development and application will contribute a lot to help strengthen the future of natural sciences in this country.

The establishment of Aerobiology as a scientific discipline in Albania will contribute to other fields that this discipline is related to including Agriculture, Allergology, Immunology, Genetics, Microbiology and Mathematics. The methodology used and the use of forecast models have been chosen after a careful investigation of similar work in other countries. The main problem related to the research work was the relatively small sample size. The decision to test the forecast models on two years made the evaluation of the models more realistic. However the examination of the pollen data of two other cities of Albania had shown that it was not possible to combine this data with the current pollen data set and so it was not possible to increase the sample size by including other data sets.

The learned methodology will help in future to adapt the current models to other areas of Albania. The start of Aerobiology in Albania was not easy as this discipline is not covered in the curricula of the Faculty of Natural Sciences. The problems related to the availability of laboratory reagents, the access to the references related to this subject and the lack of electricity made the process of the integration of this discipline very difficult.

The support of the National Pollen and Aerobiology Research Unit and the European Pollen Data Bank had a decisive role in facilitating this. The process of obtaining the metereological data from the Metereological Institute was also difficult but the problem was overcome eventually. The wind data was obtained from the Airport weather station which is further away from the Meteo data site. The wind data seems not to make any contribution to explaining variation in the pollen data and maybe this is related to the considerable distance this station is from the location of the pollen sampler in Tirana.

If the current research could be continued, the forecast models would benefit from the longer data set. The small data set used for the current research did not give the capacity to cope with the small differences specialty for the anomalous years. These could easily produce bias in a small data set.

The definition of the pollen season was carefully chosen by investigating similar works. The current work presents the definition of the pollen season for Grass, Olea and Urticaceae only in retrospective ways (methods). Due to the lack of identified thresholds that cause allergic reactions in the population of Albania the prospective methods could not be used in the research. However, more collaboration with allergologists and those who deal with allergic patients will contribute to the detection of the thresholds that cause allergies from Grass, Olea and Urticaceae pollen.

The thresholds used to test the accuracy of the forecast models for Grass, Olea and Urticaceae were based on similar work in Italy and Spain. Again the larger pollen data set will allow researchers in the Aerobiology field to investigate and fix characteristic thresholds for Albania especially for Tirana city. The methodology used in the research was based on similar studies in other countries with similar climates like Spain and Italy. For example the thresholds used in the "Spring" study of pollen forecast in various EU countries (ref). However due to the cultural and other differences it is likely that the thresholds are different. More future work is needed to explore the different aspects of the methodology which could be appropriate to our region and our pollen data.

The definition of the pollen peak, especially its start and end has been carried out through a lot of investigation and consultation with similar work. The definition of the start of the peak period was based mostly on the Pathirane [1975] work and further attempts need to be made for its improvement to separate the pollen season to low, medium and high levels.

The division of the pollen season in relation to what happens from year to year might also be useful and needs to be investigated more carefully as the division of the pollen season is not related to the symptoms so it will be useful to have a division based on allergic response.

Further improvement in forecast models could be made if the vegetation map for the main allergenic taxa and wind directions would be included.

More information on the vegetation map using wind direction or trajectories might be useful to help in the construction of the robust forecast models.

The use of the neural network in the research allowed the building of some models for forecasting daily variations of Grass, Olea and Urticaceae. The availability of using such a technique was possible only at the end of the research work. It helped also to use this technique as an alternative work to the analysis performed using SPPS. The technique is quite quick and overcame a lot of problems which can easily be encountered by other programmes. The technique could be easily applied with the support and the assistance of mathematicians. It leads to the better collaboration between biologists and allergologists.

All the information produced, the forecast models and the thorough investigation of the characteristics of the pollen season for the main allergenic taxa will contribute to better diagnosis of allergic people and improvement of their management.

The strength of the research is based on the acquisition of appropriate methodology to be used in similar work in the future, the possibility of using the forecast models for public information and the ability to collaborate with other Aerobiologists for the future publications etc. The skills learned will facilitate collaboration with the allergologists and related subjects. It gives Aerobiology in Albania a better future and perspective. The use of the neural network in Albania is quite original. The possibility to show pollen forecasts models on websites and other related ways creates a wide opportunity to spread the information to the public and doctors and related professionals.

The current work will help to strengthen the collaboration between the Aerobiology in Albania and the European Pollen Network.

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APPENDIX A: THE POLLEN DAILY VARIATIONS OF MOST ALLERGENIX TAXA IN ALBANIA FOR 1995, 1996, 1998 AND 2002

Fig. A1-a

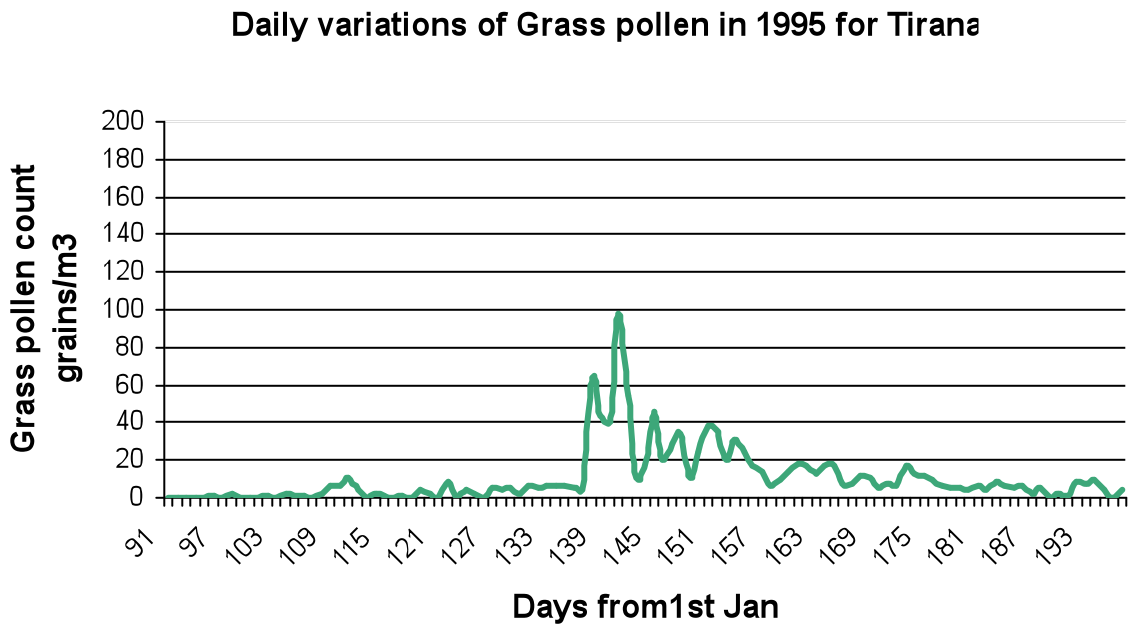
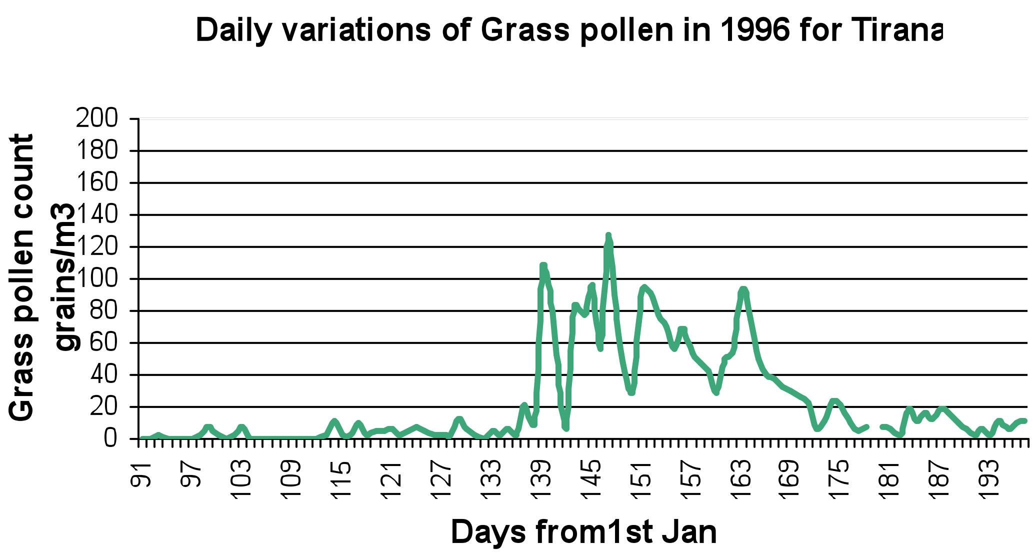


Fig. A1- b



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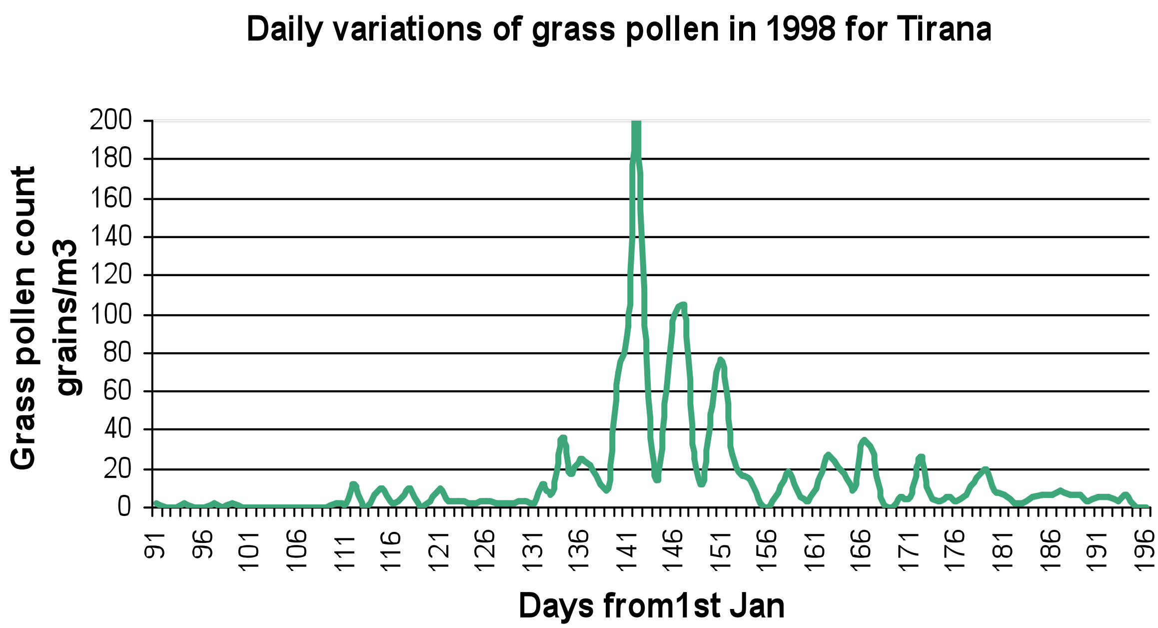


Fig. A1-d

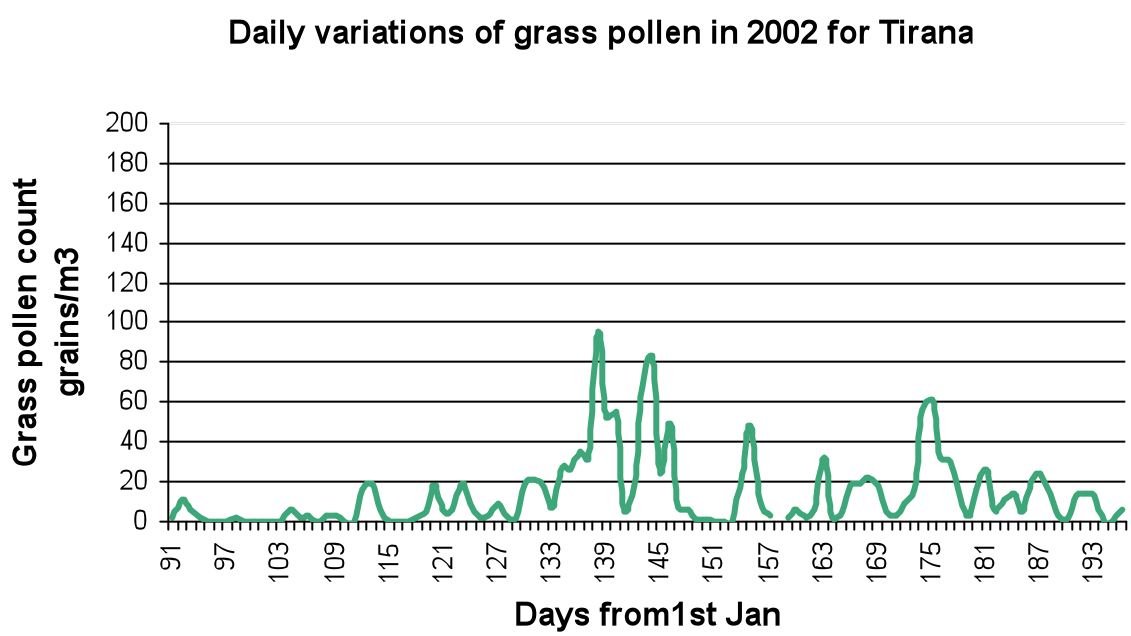
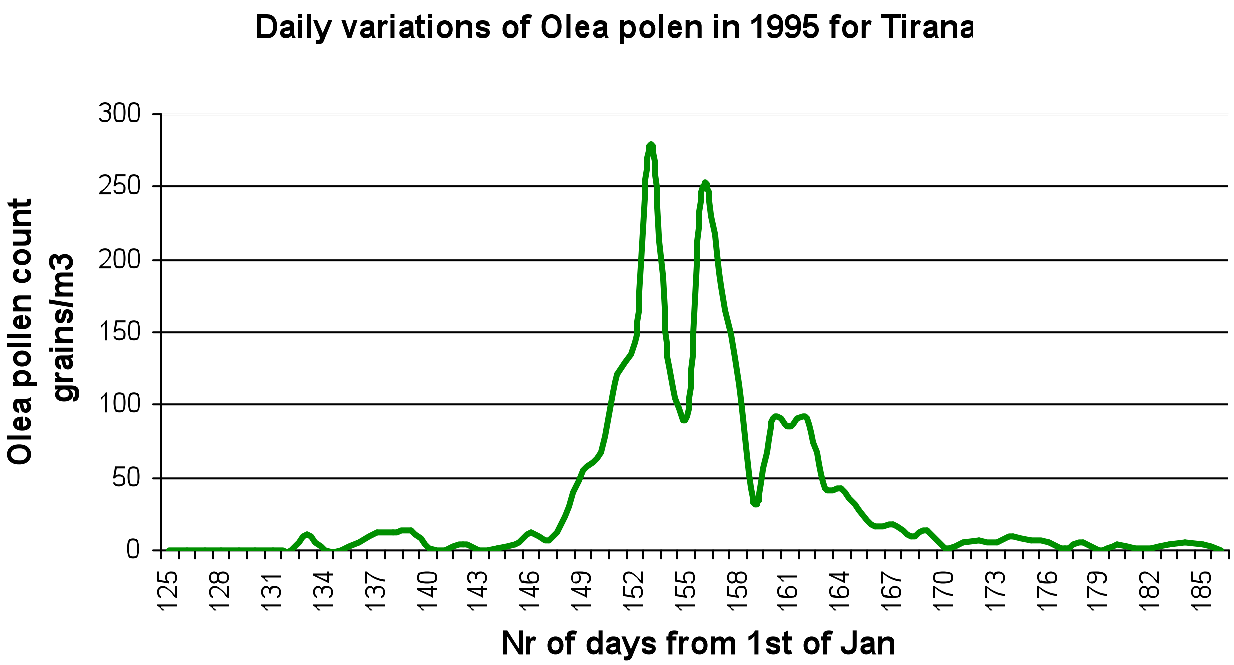


Fig. A2- a



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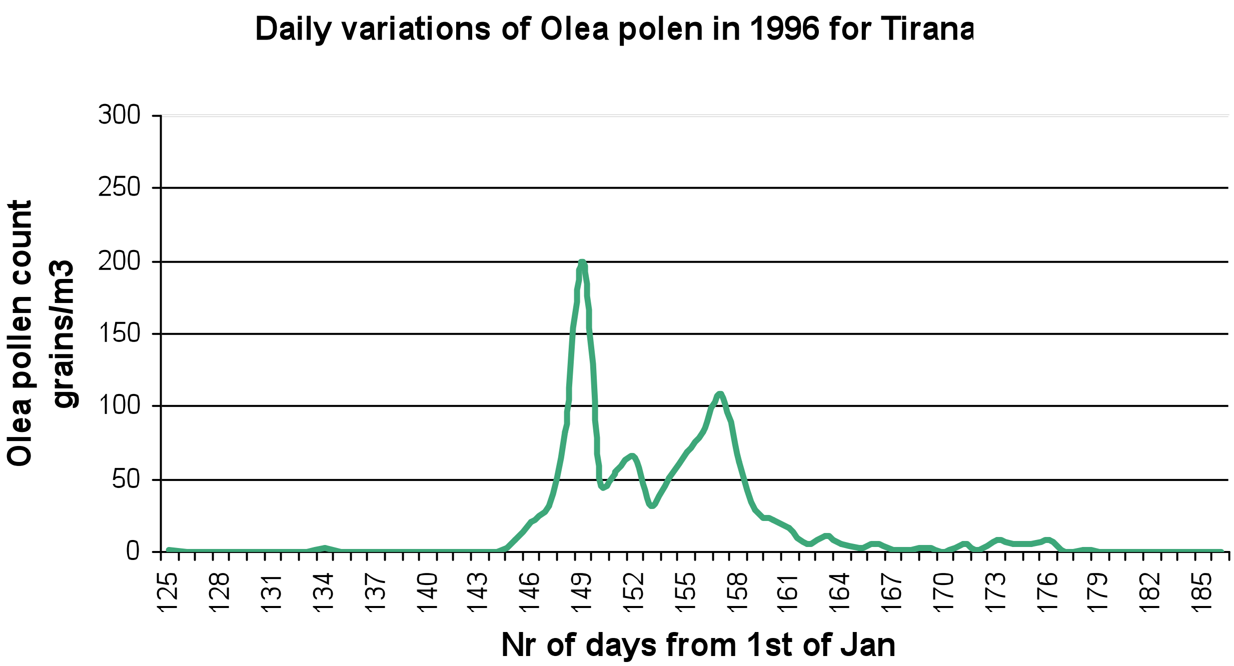
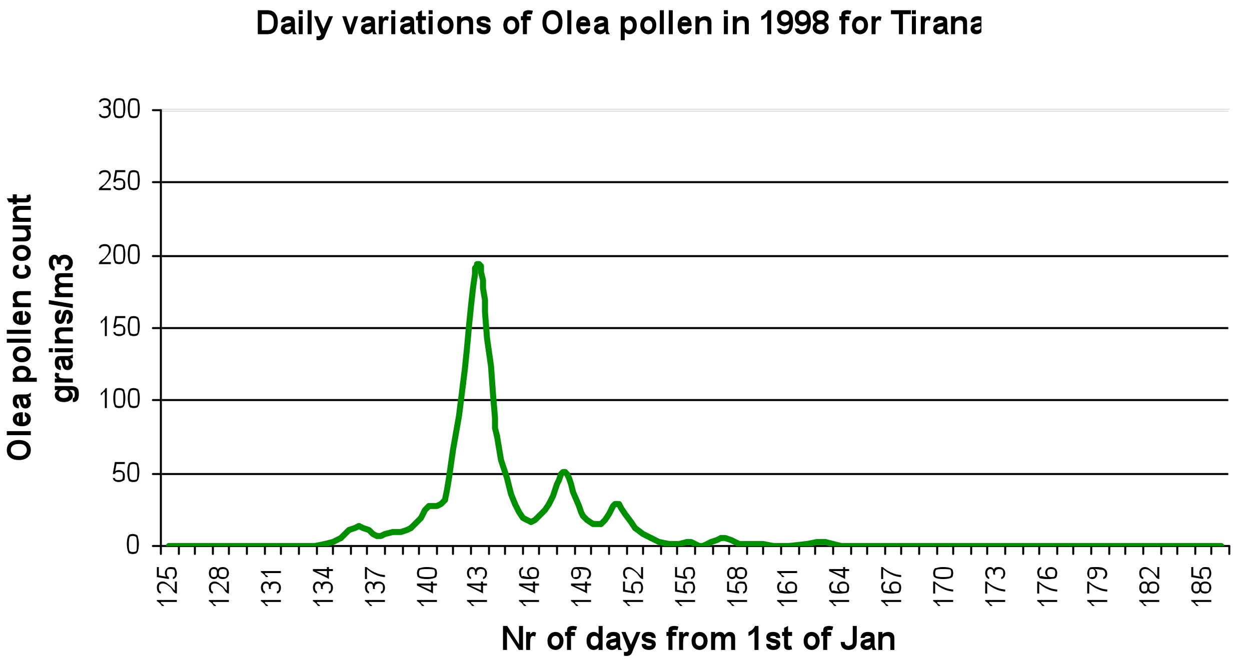


Fig. A2- c



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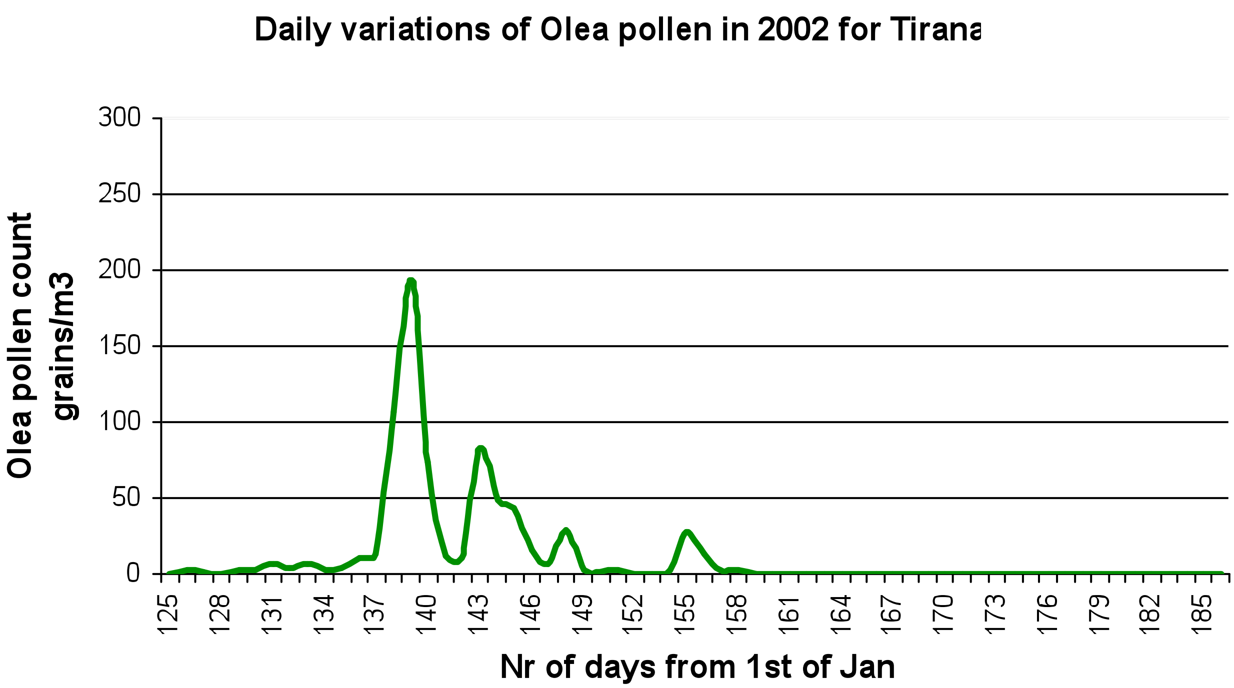

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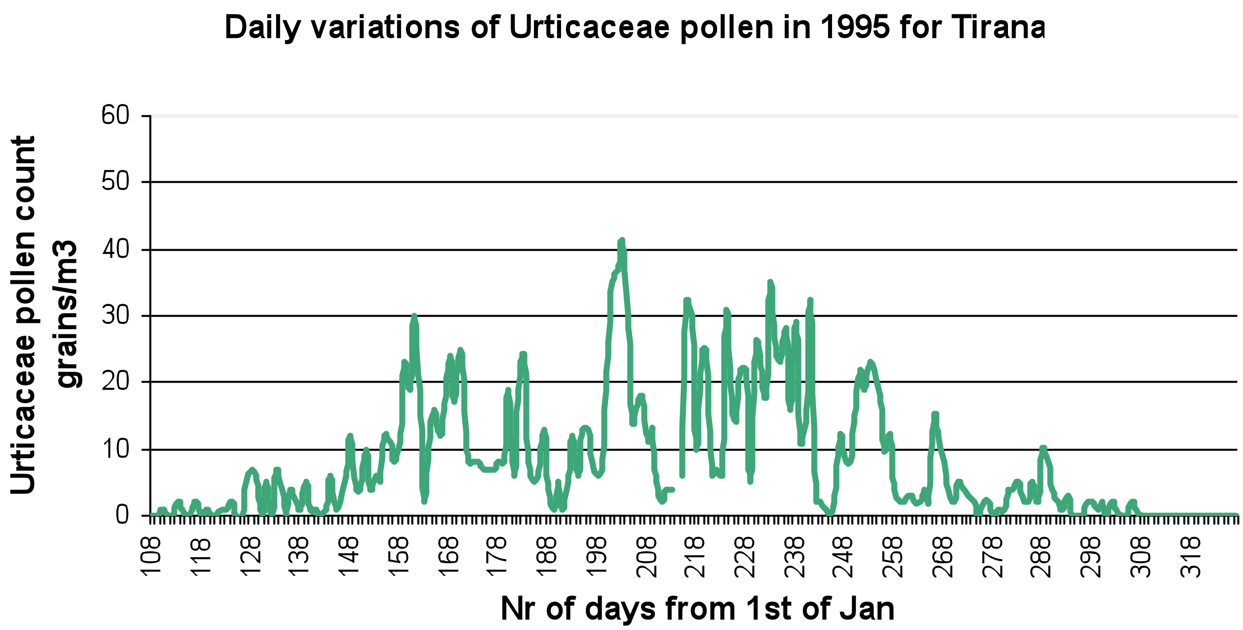
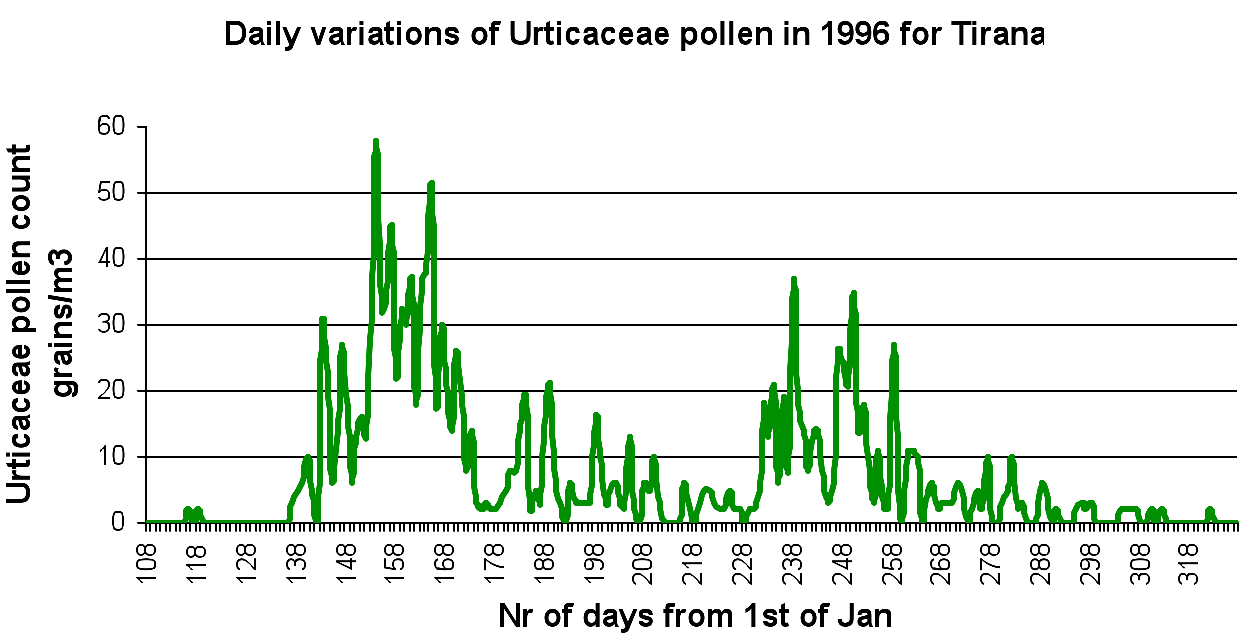


Fig. A3-b



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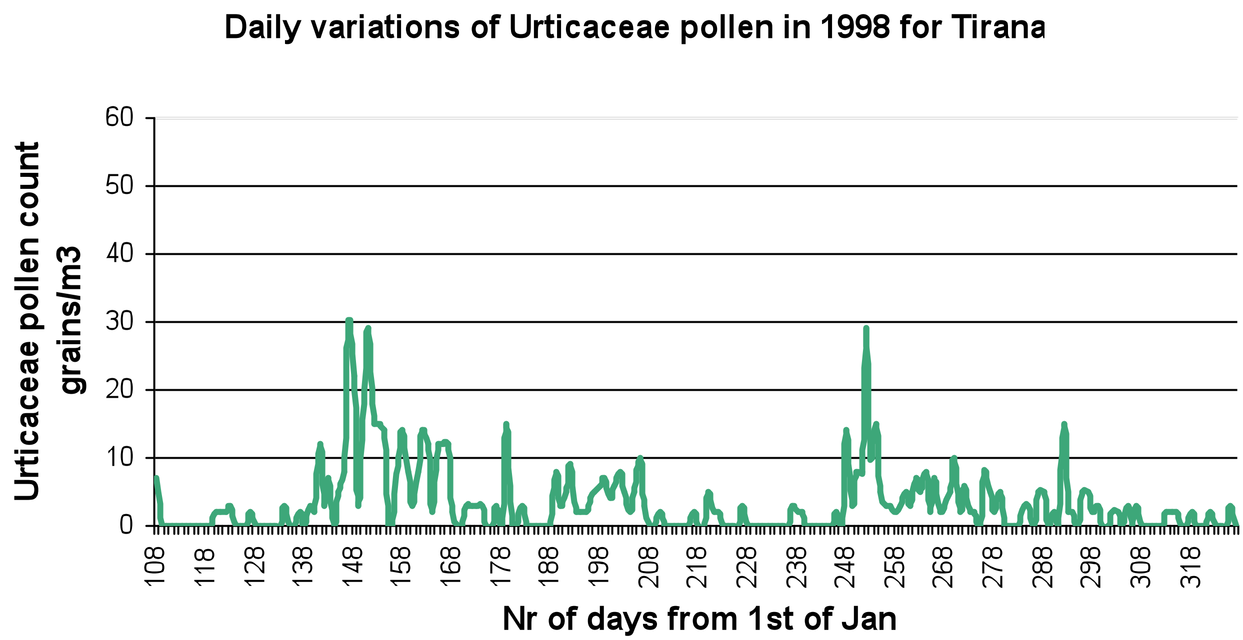

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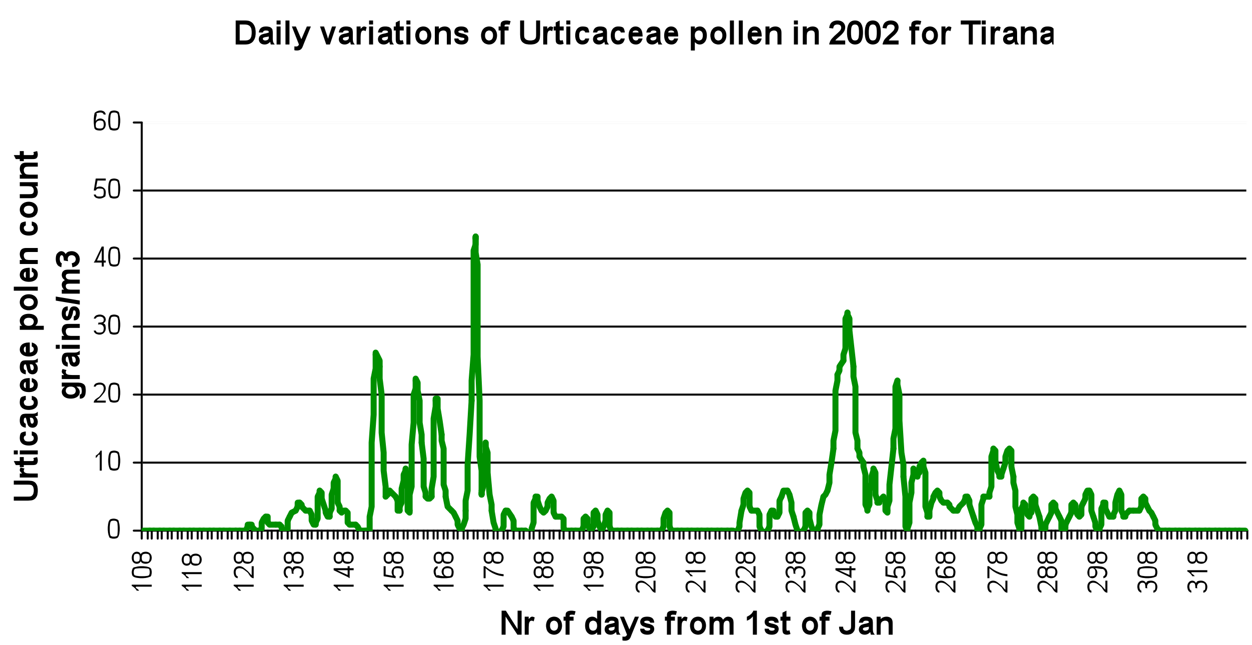

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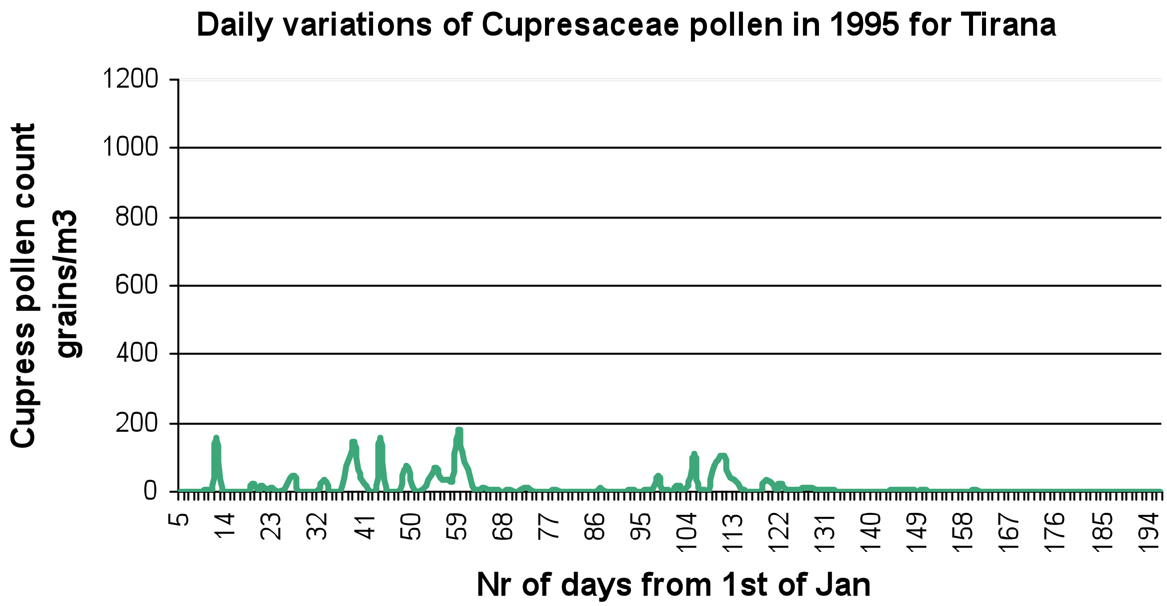

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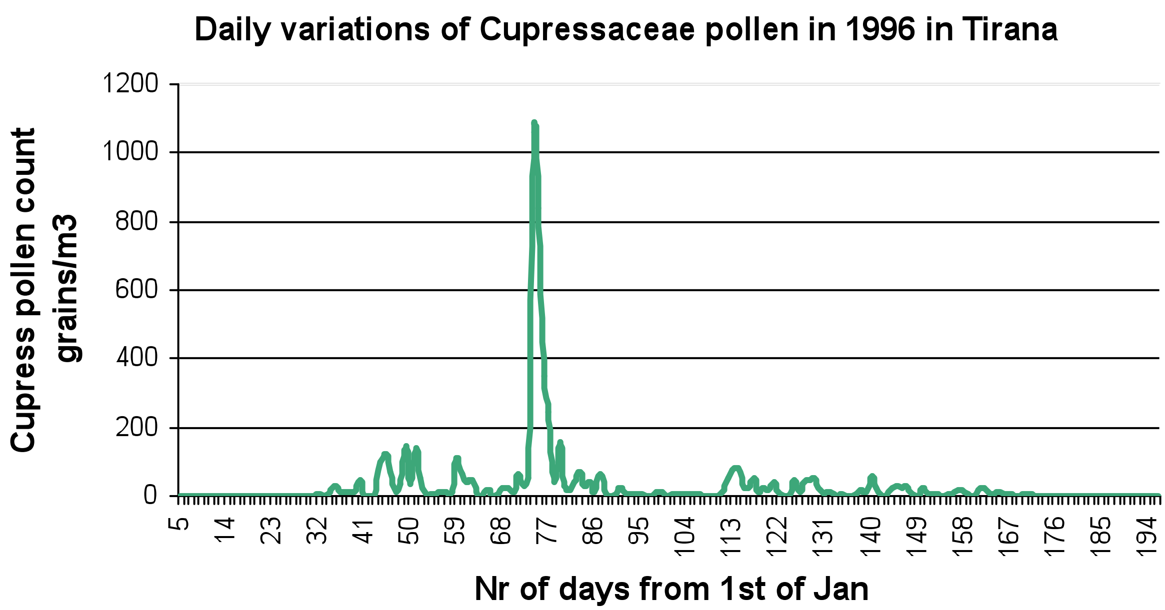


Fig. A4- c

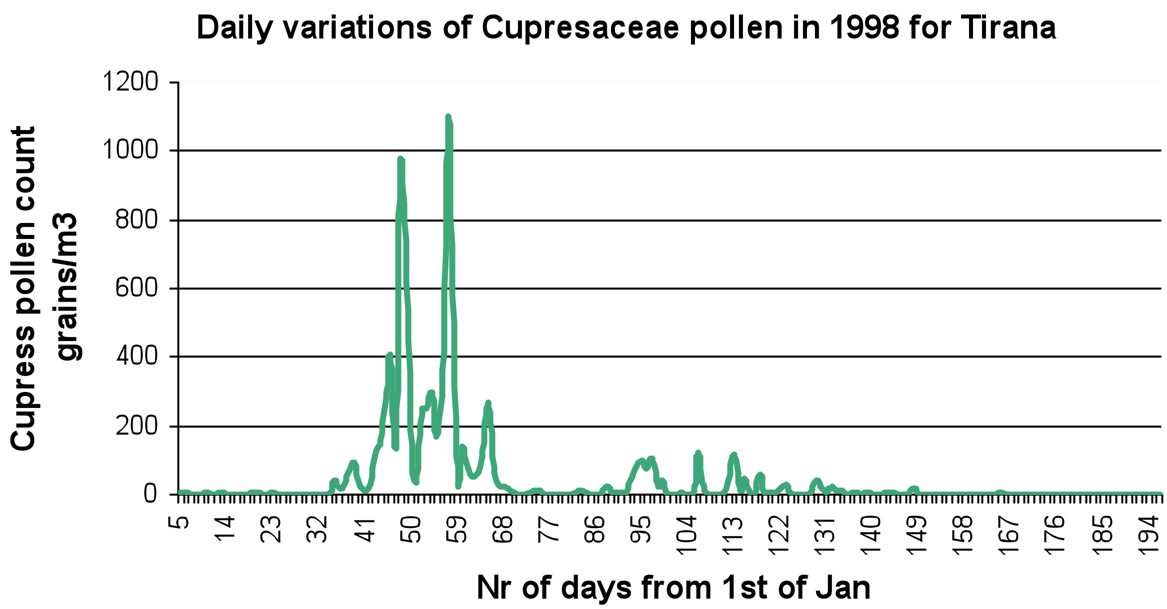
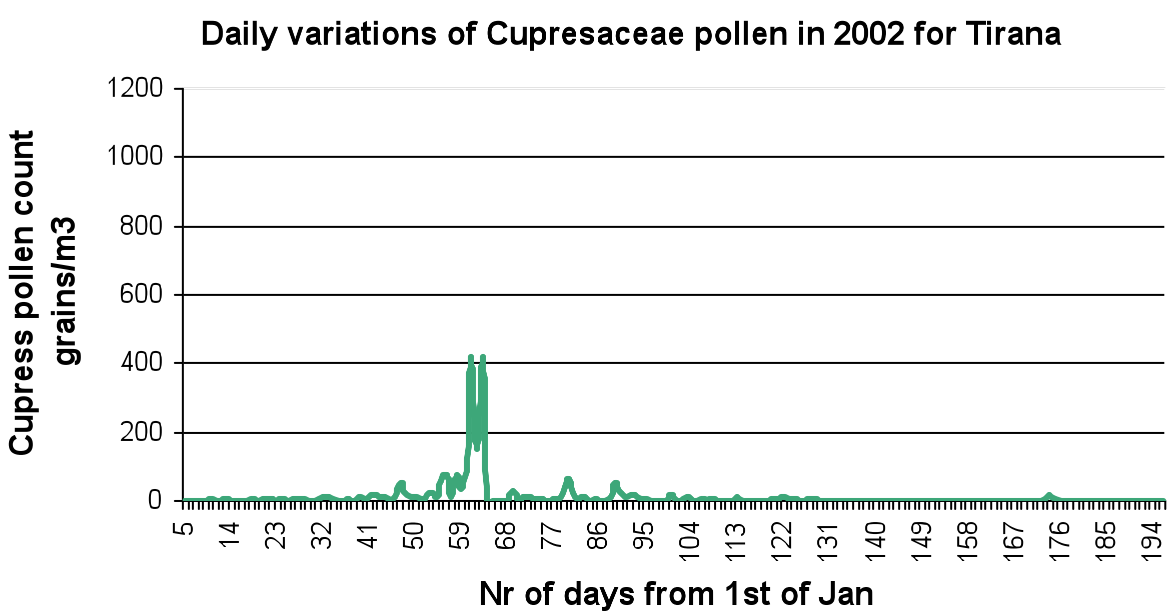


Fig. A4- d



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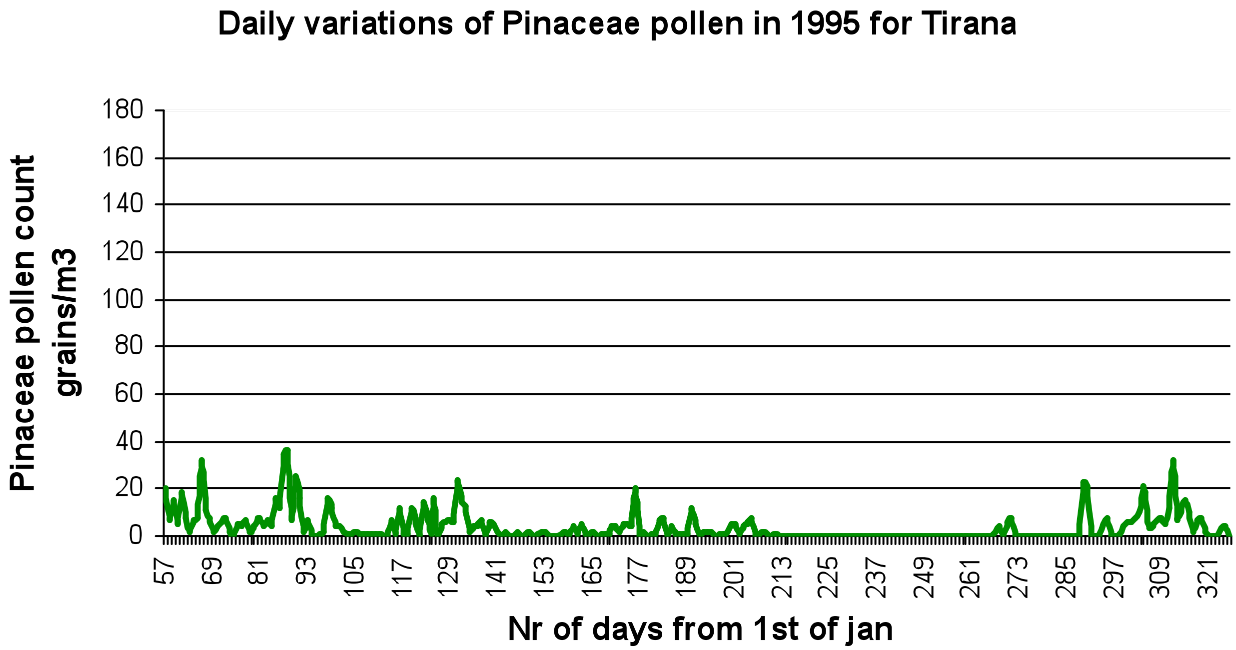


Fig. A5- b

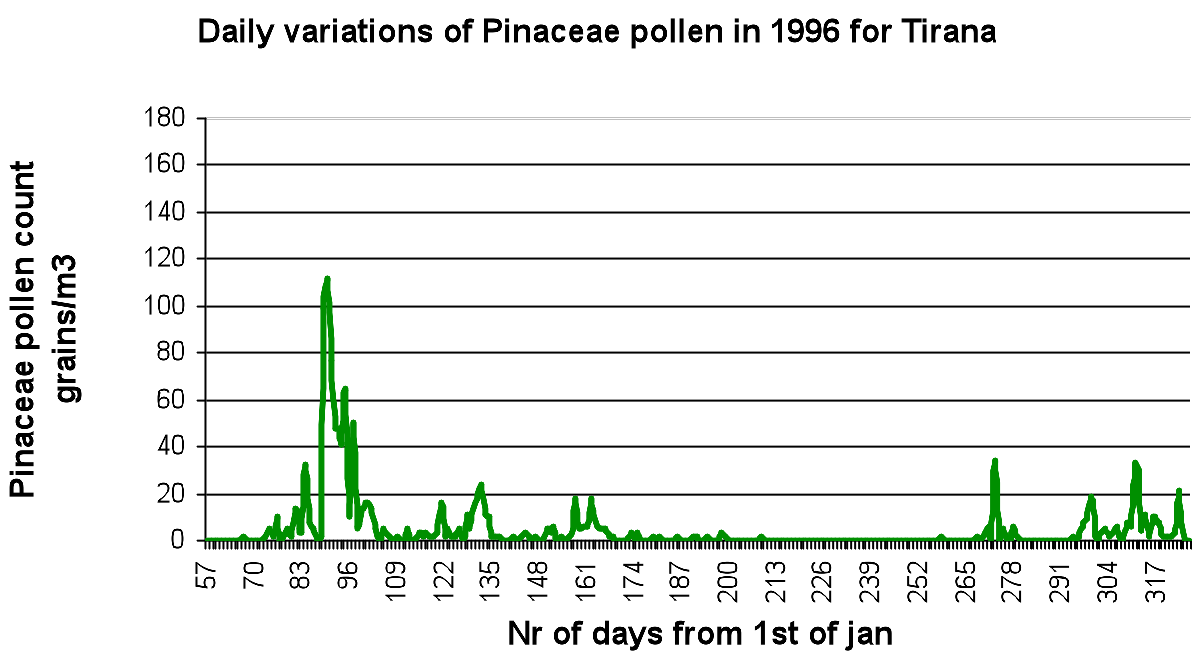


Fig. A5-c

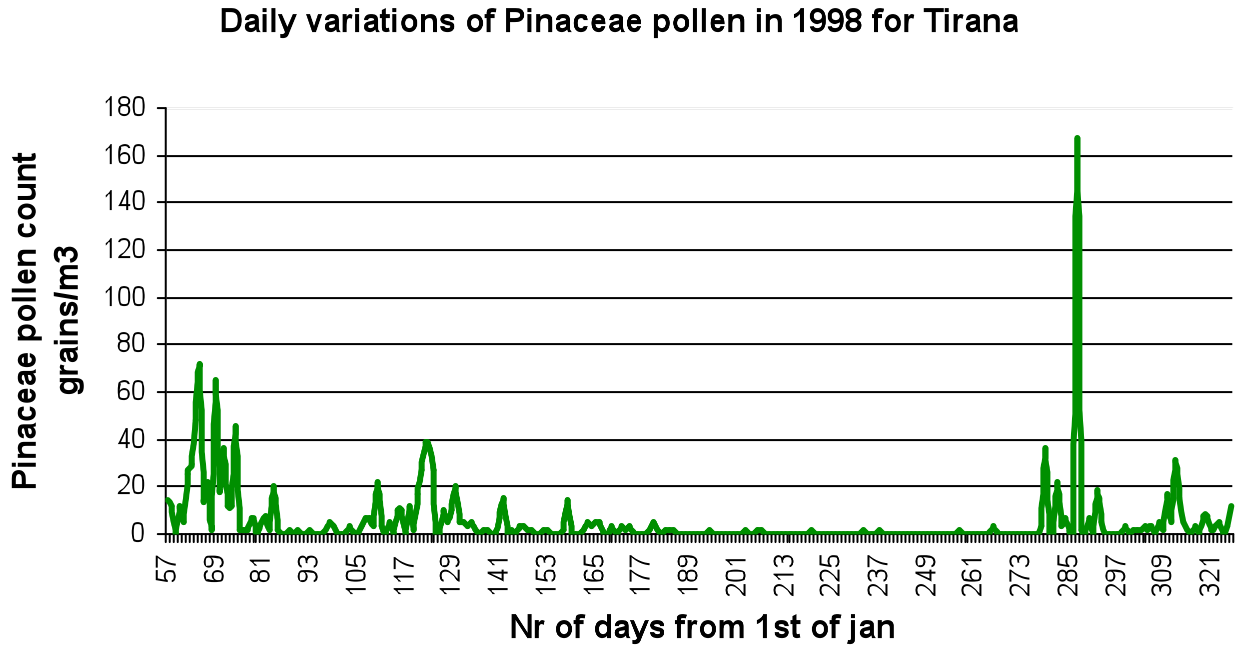
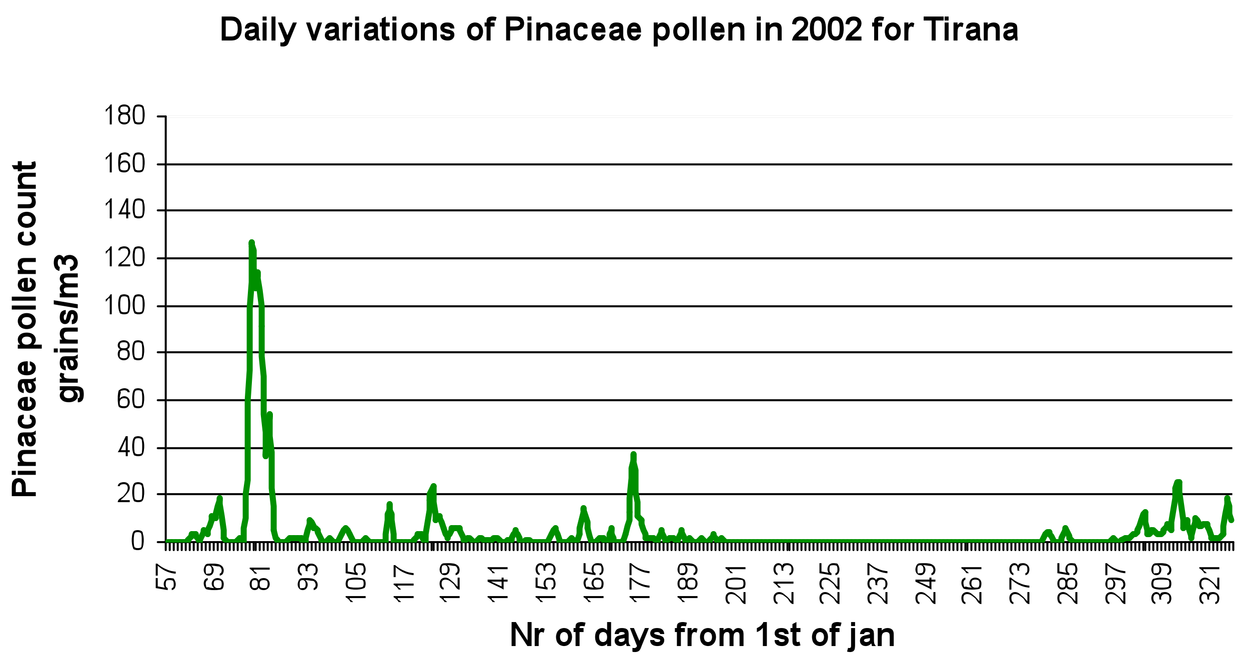


Fig. A5-d



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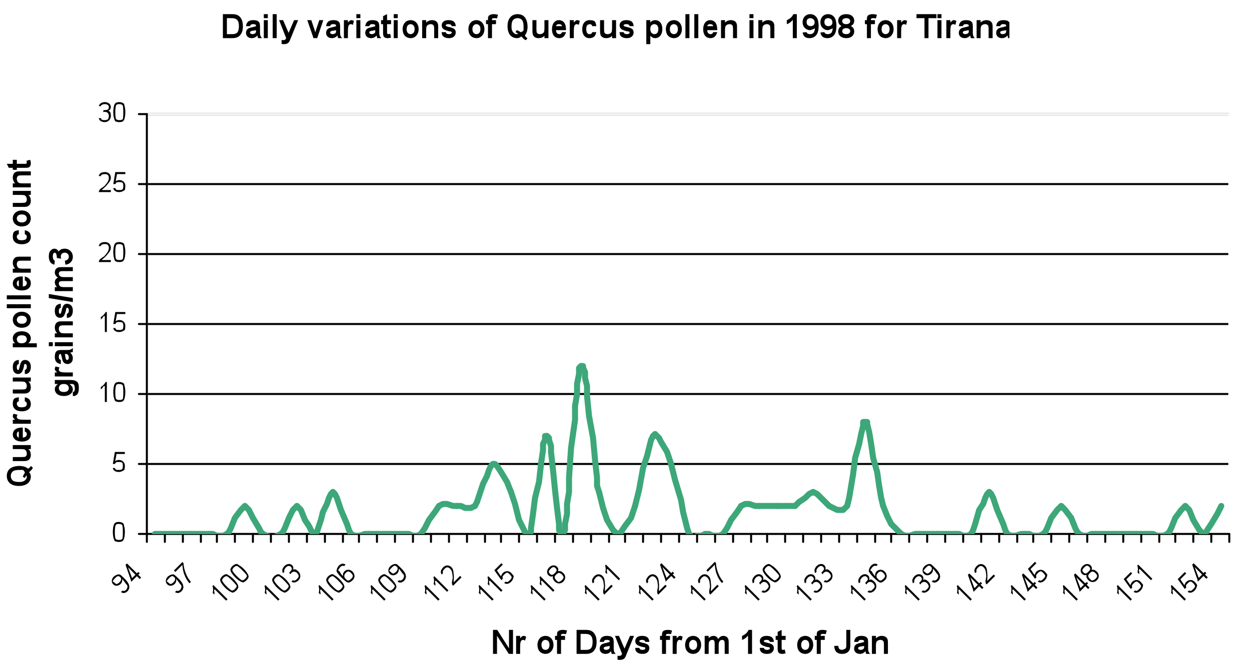


Fig. A6- b

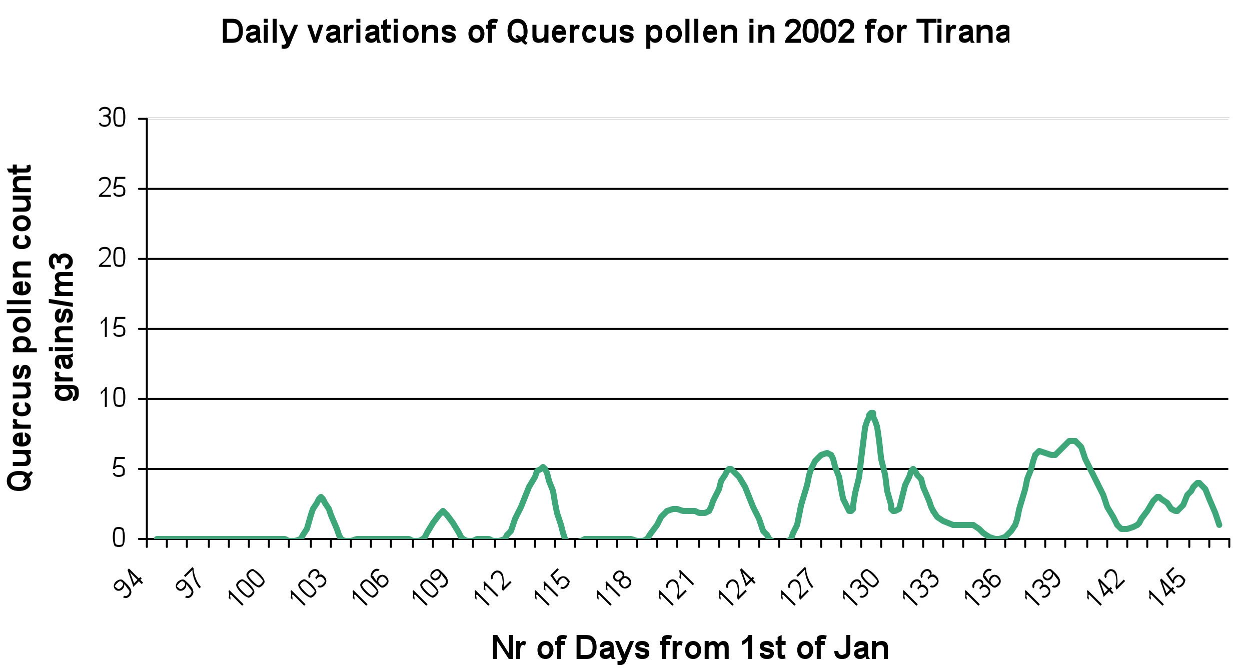


Fig. A7- a

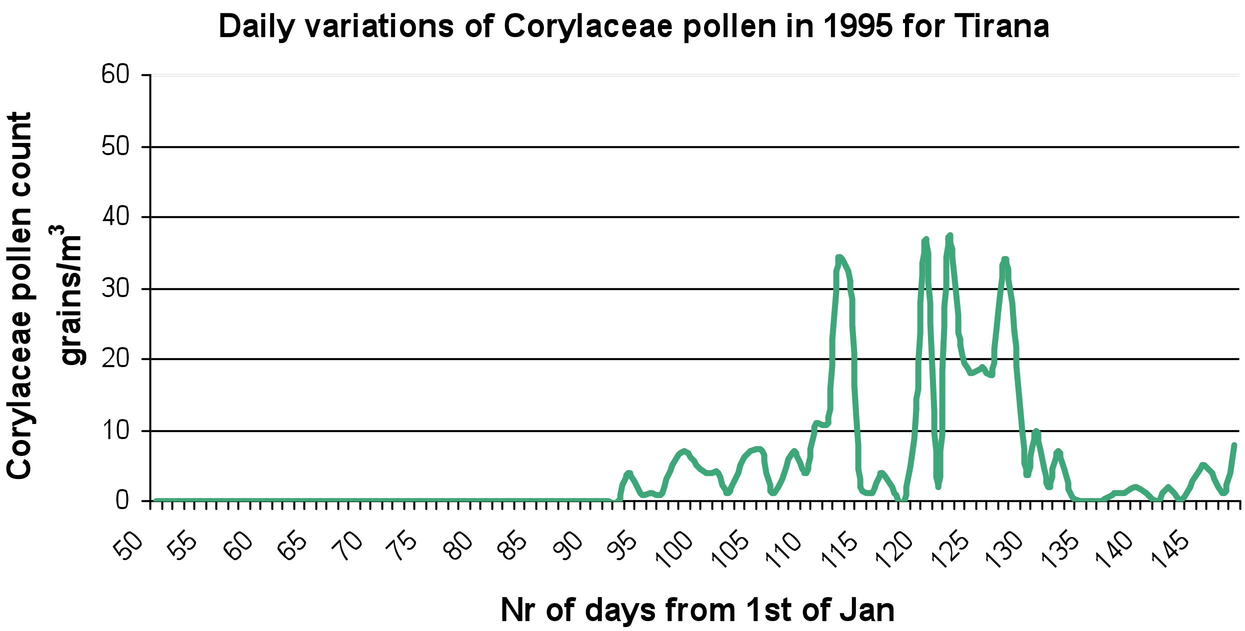


Fig. A7- b

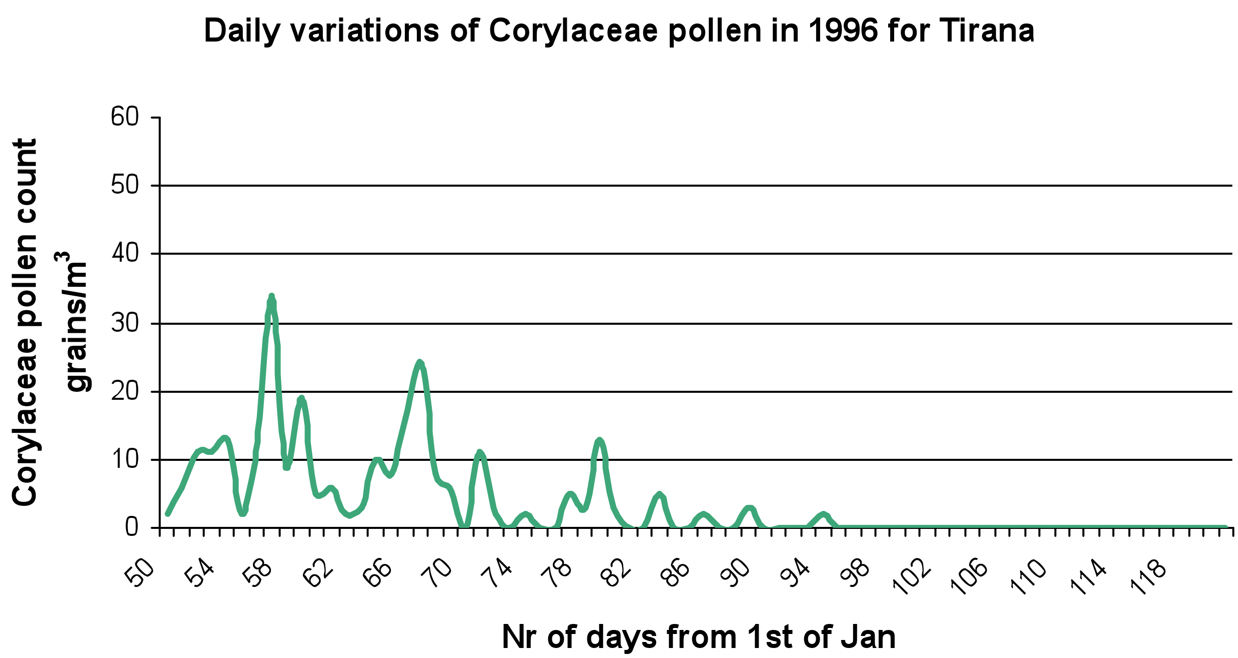


Fig. A7- c

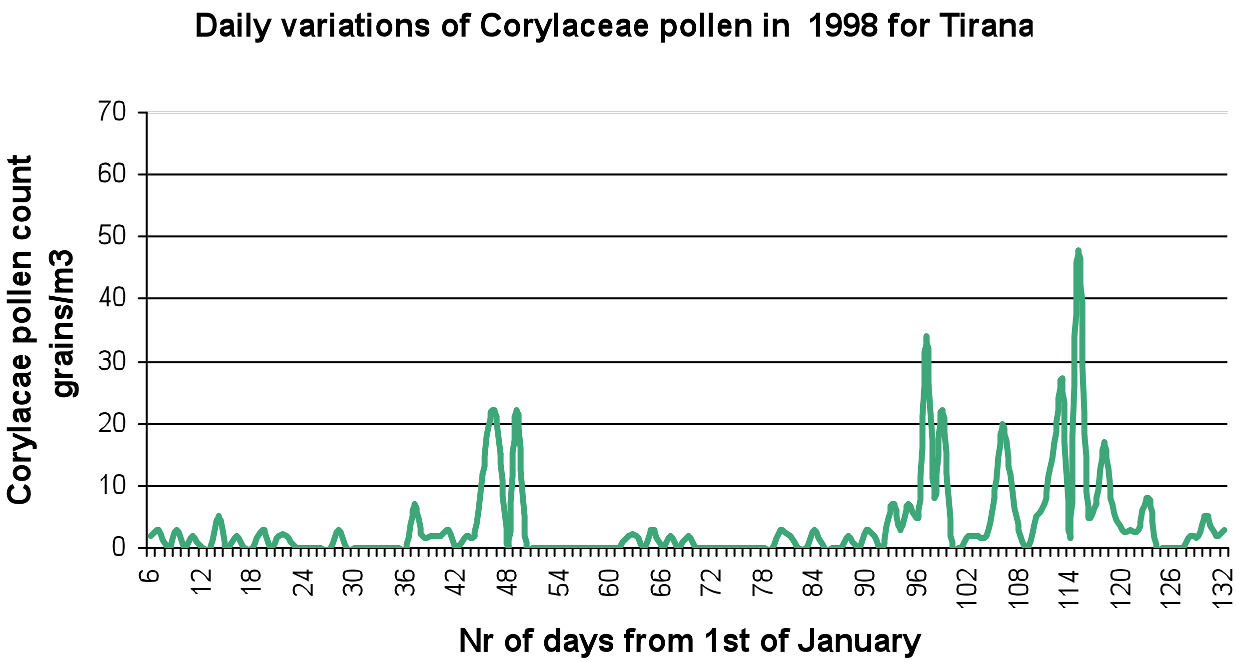
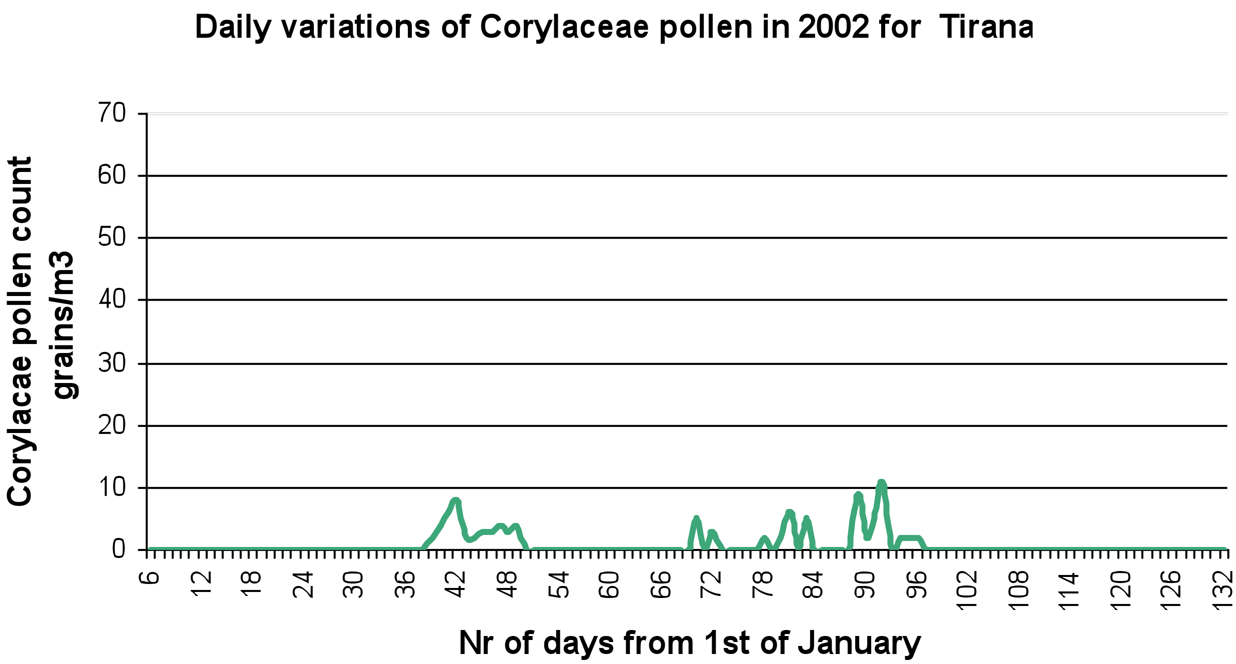


Fig. A7- d



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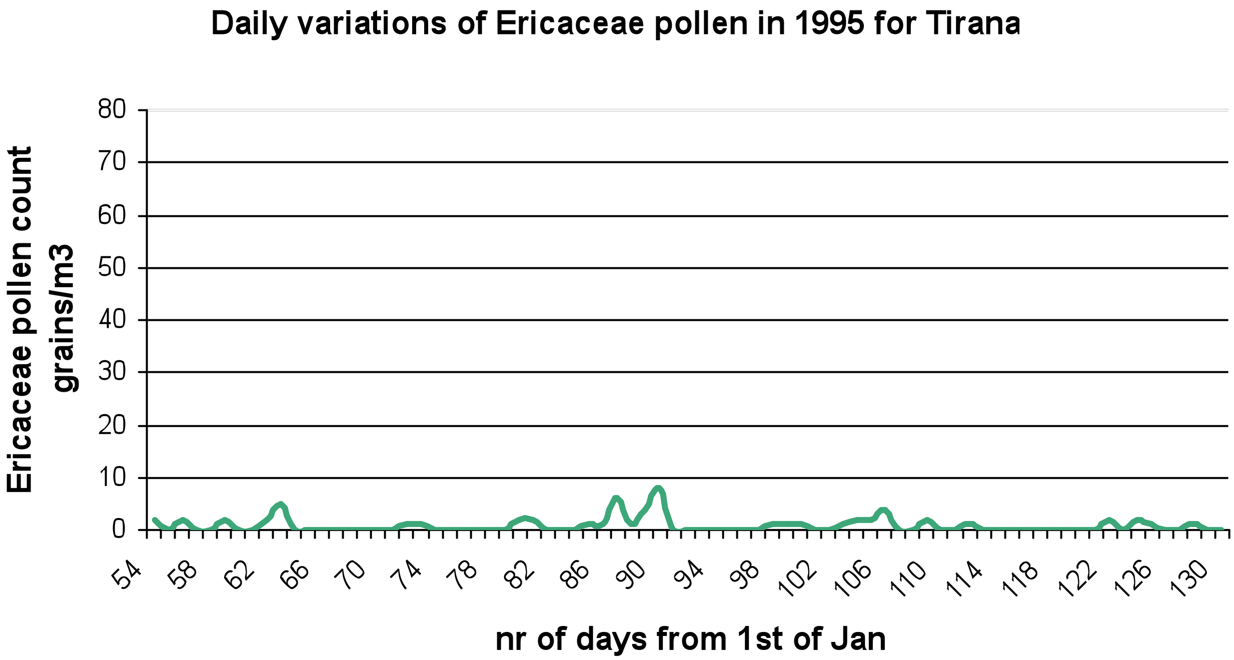


Fig. A8- b

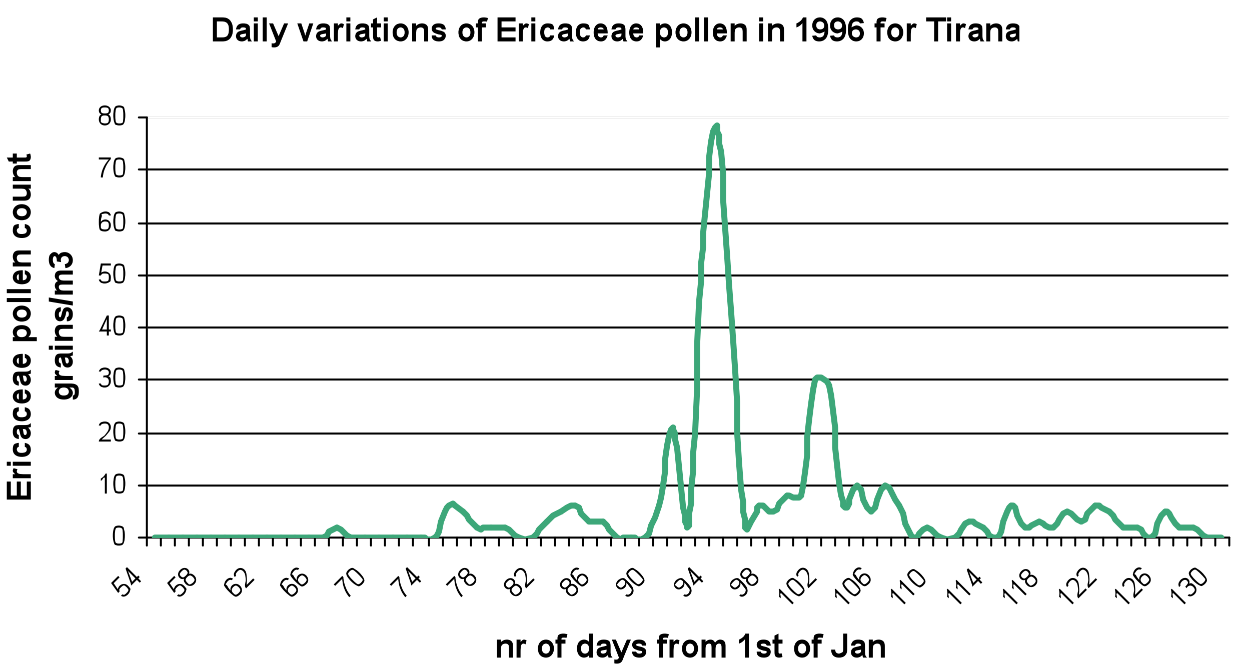
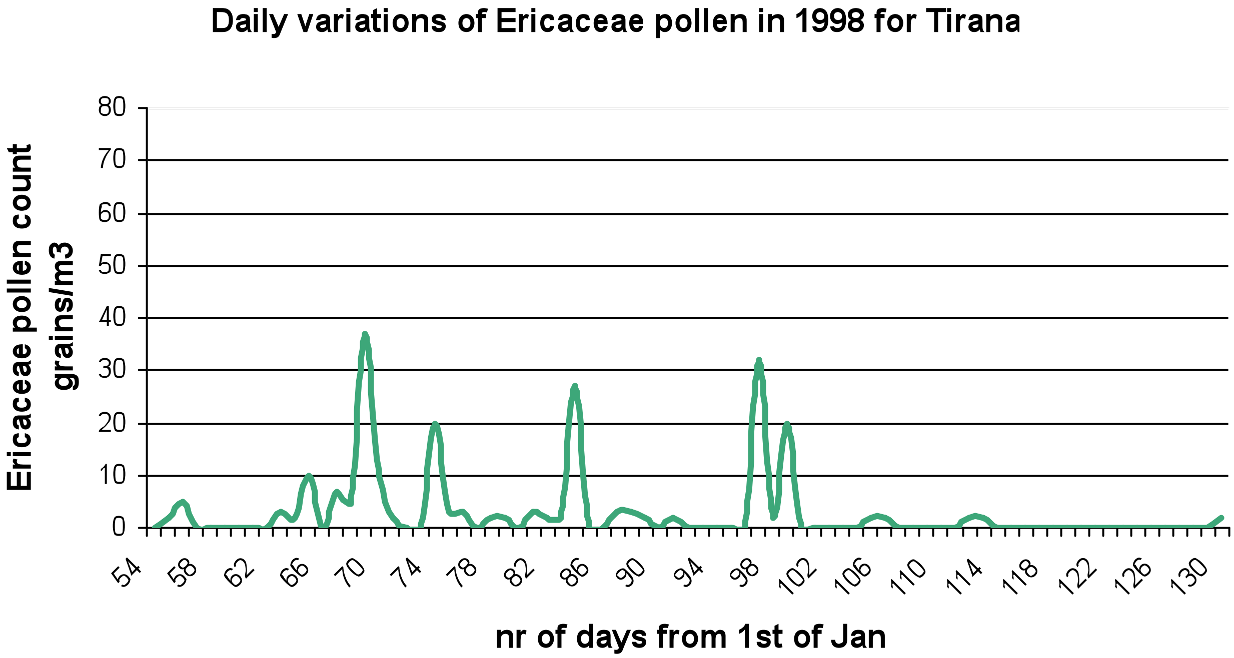


Fig. A8- c



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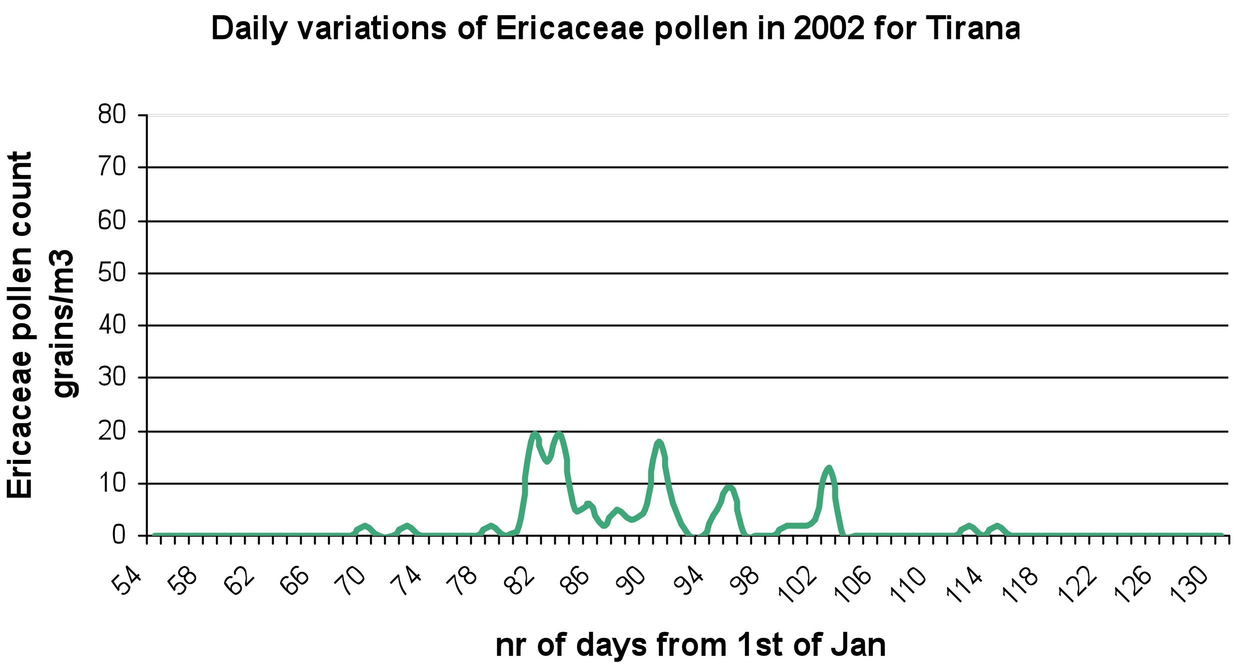

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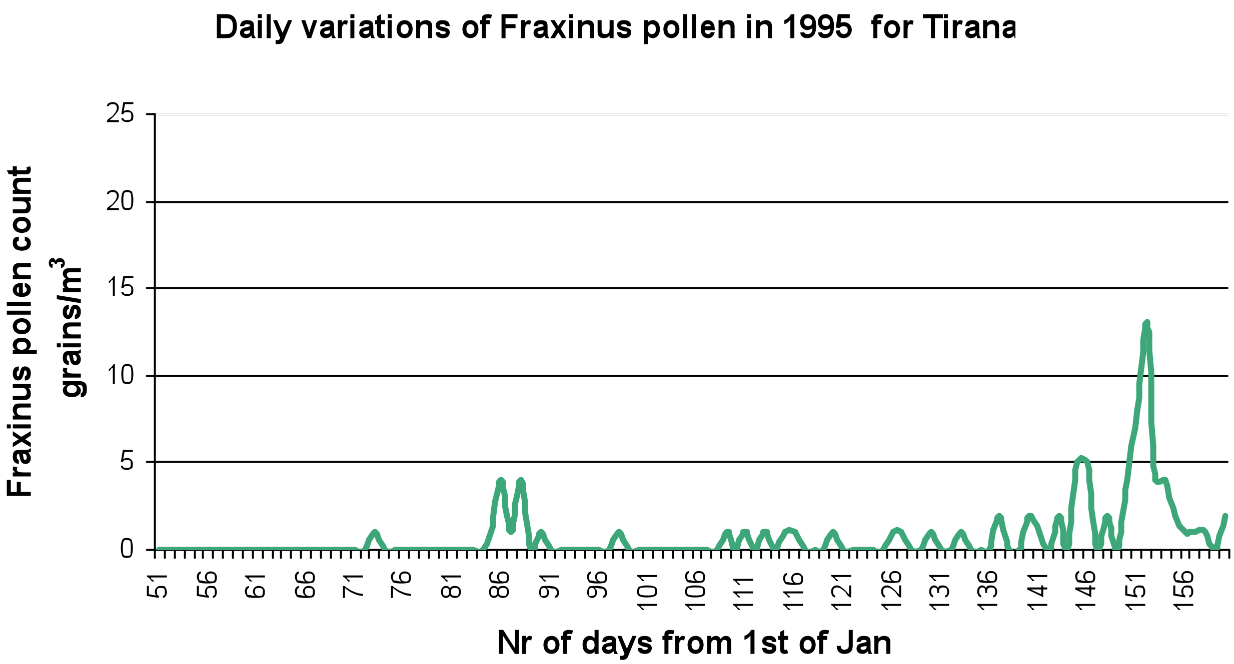


Fig. A9- b

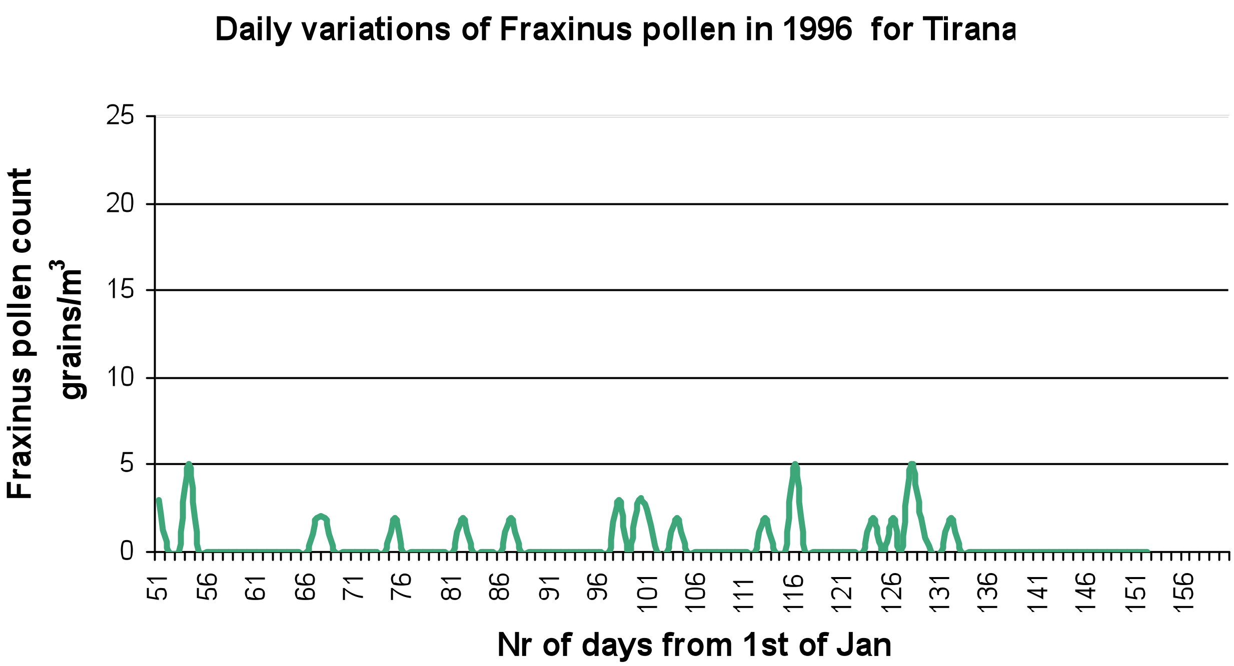


Fig. A9- c

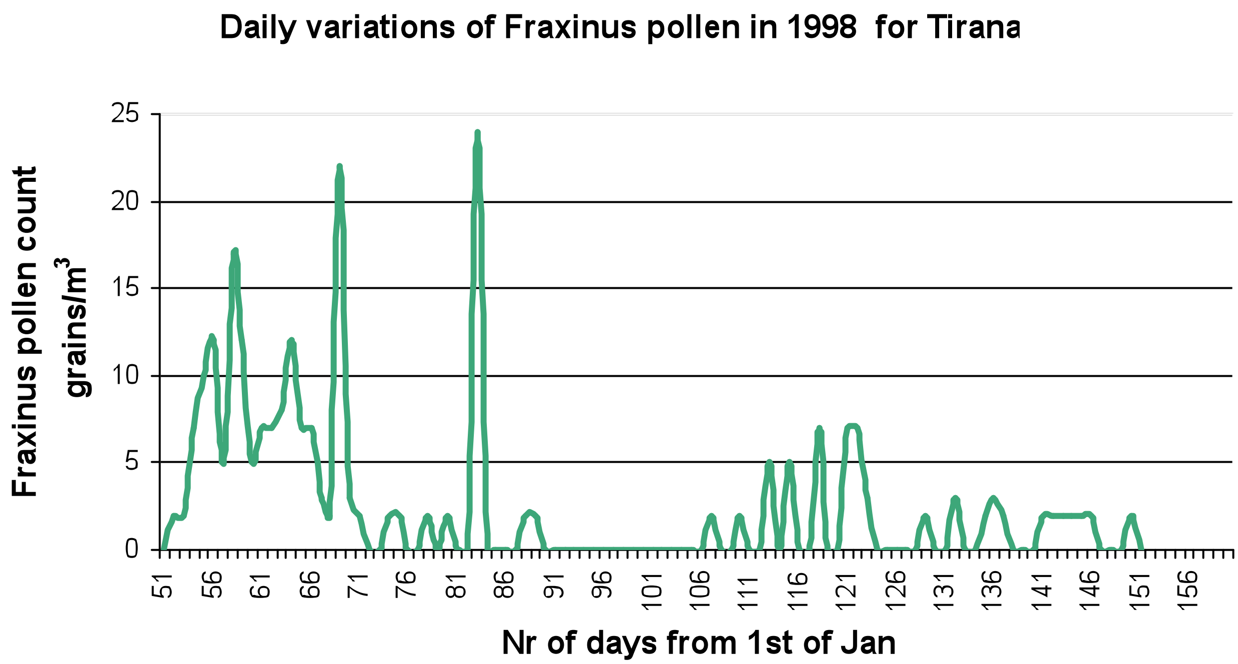
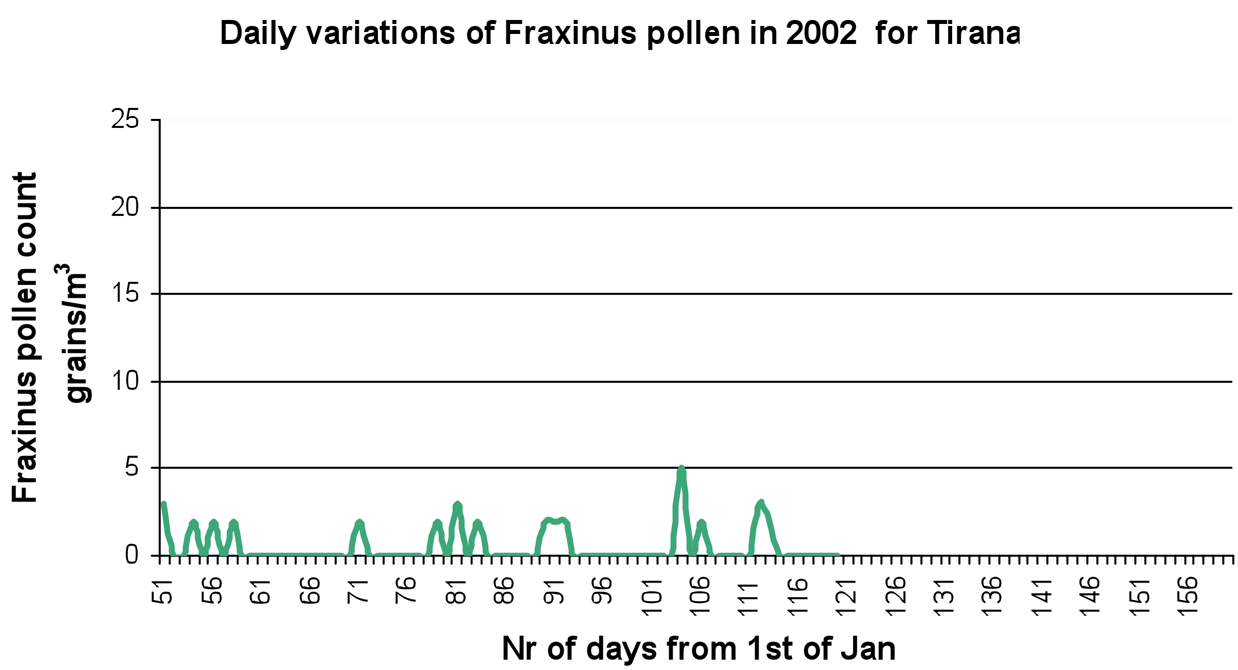


Fig. A9-d



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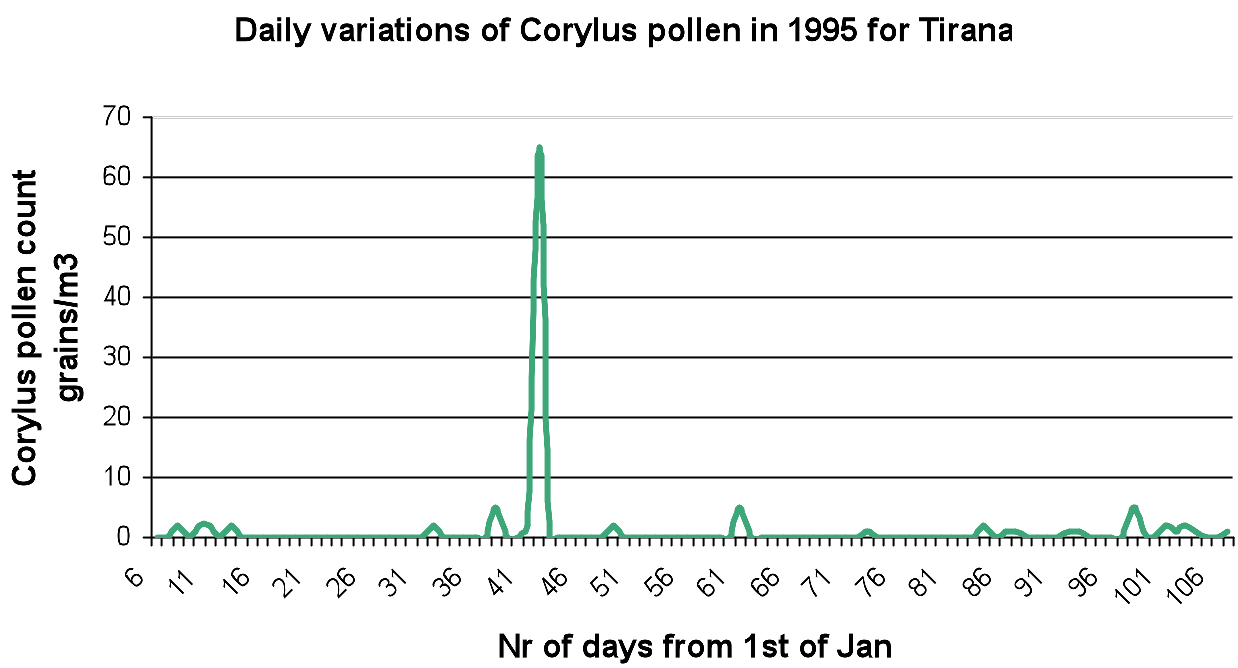

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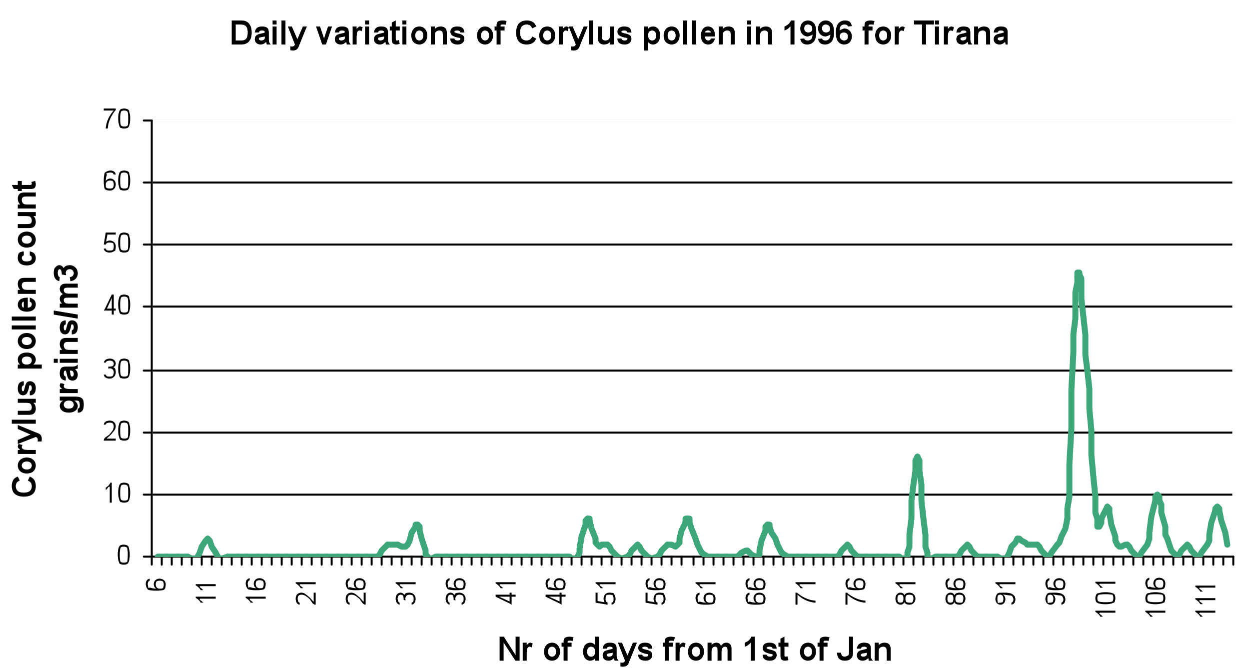

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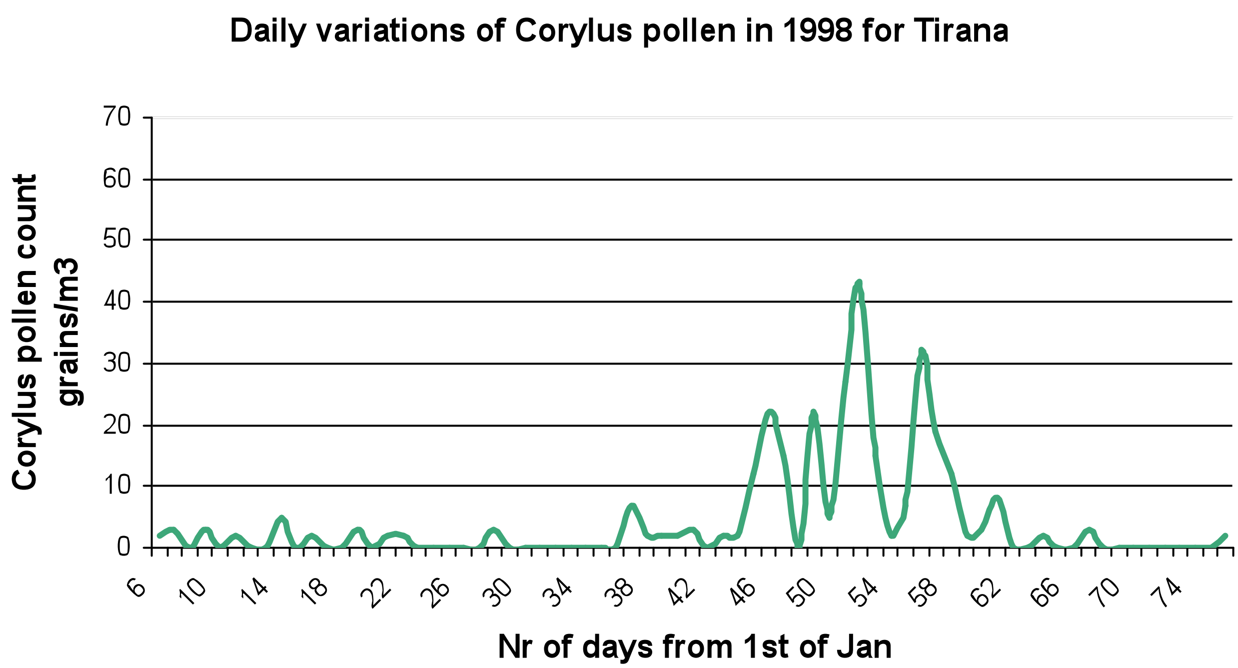

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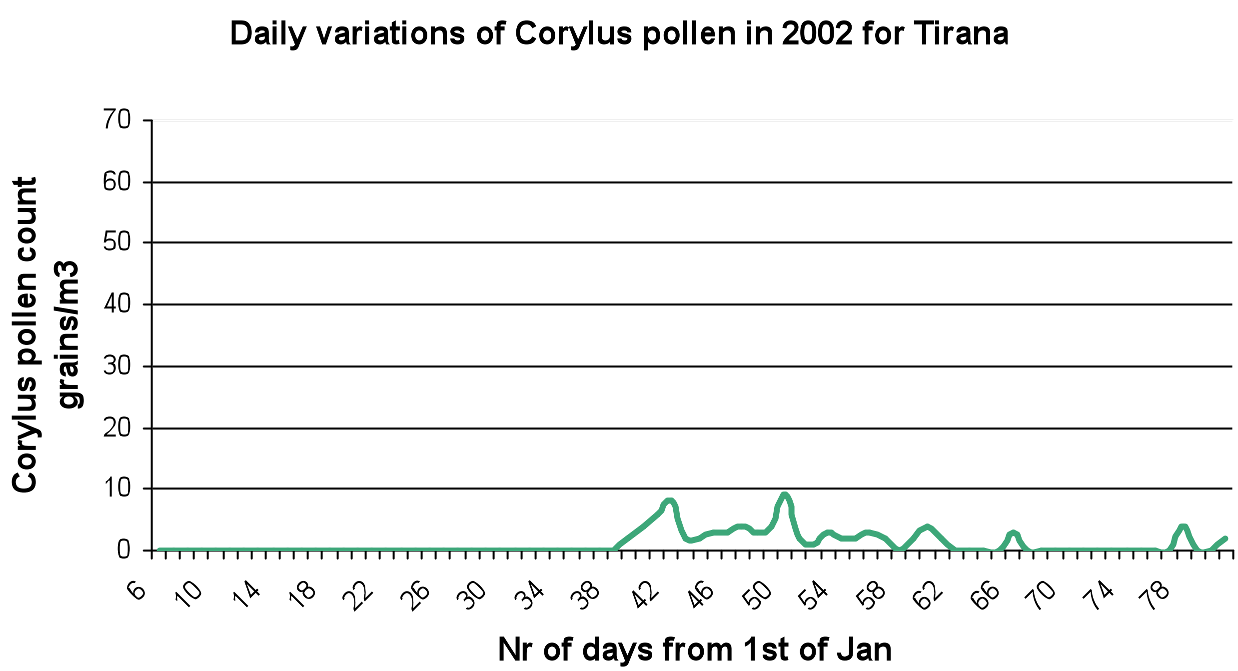

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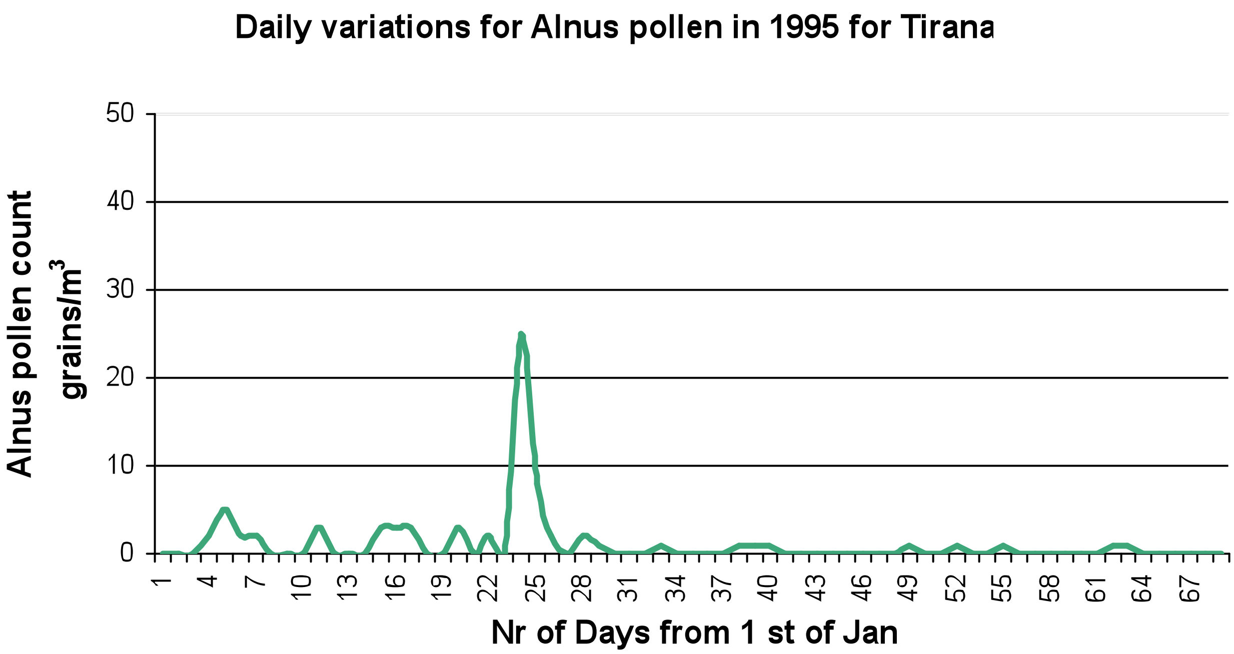

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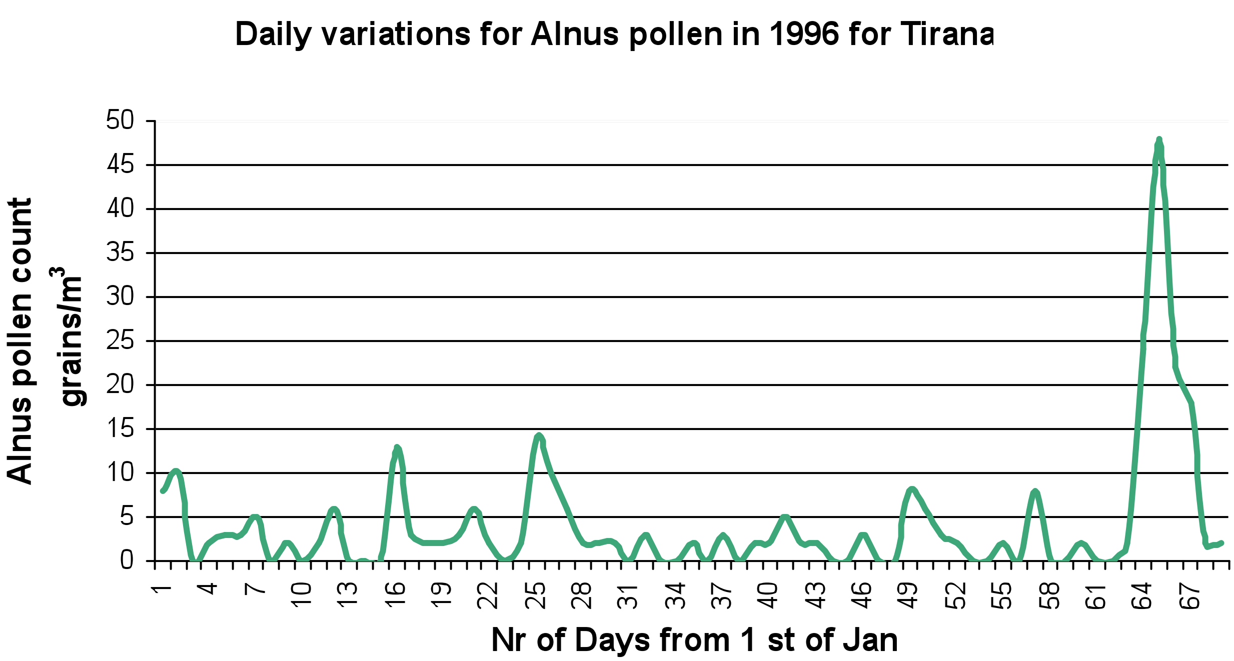

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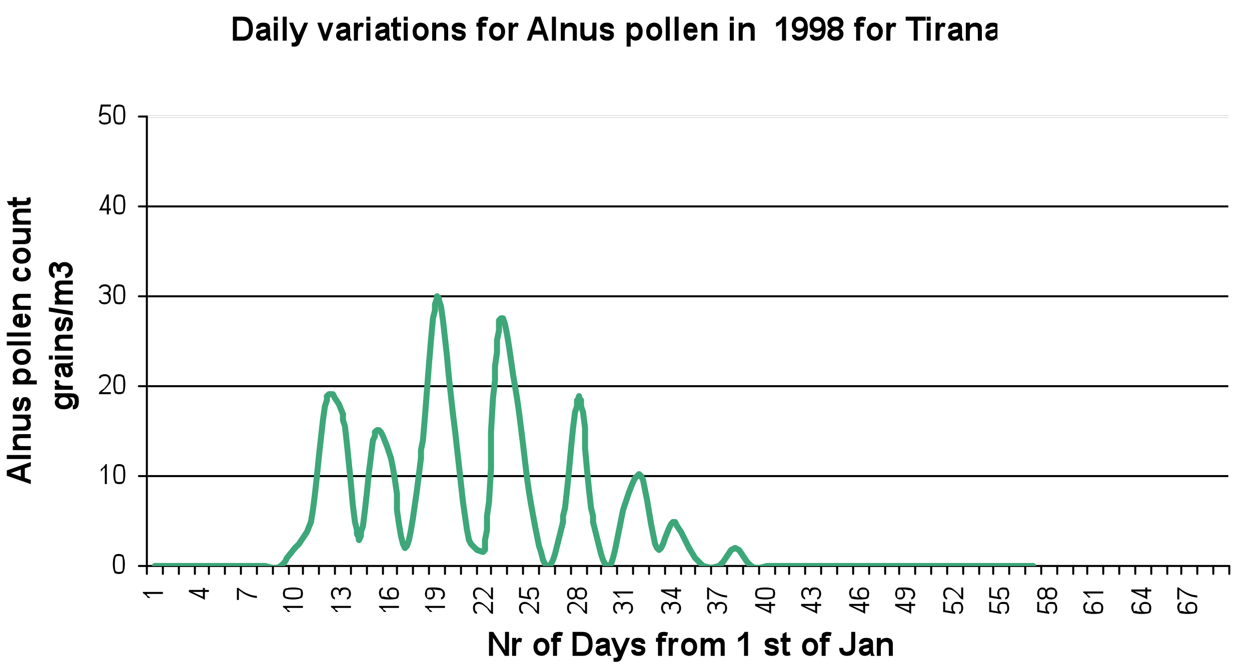
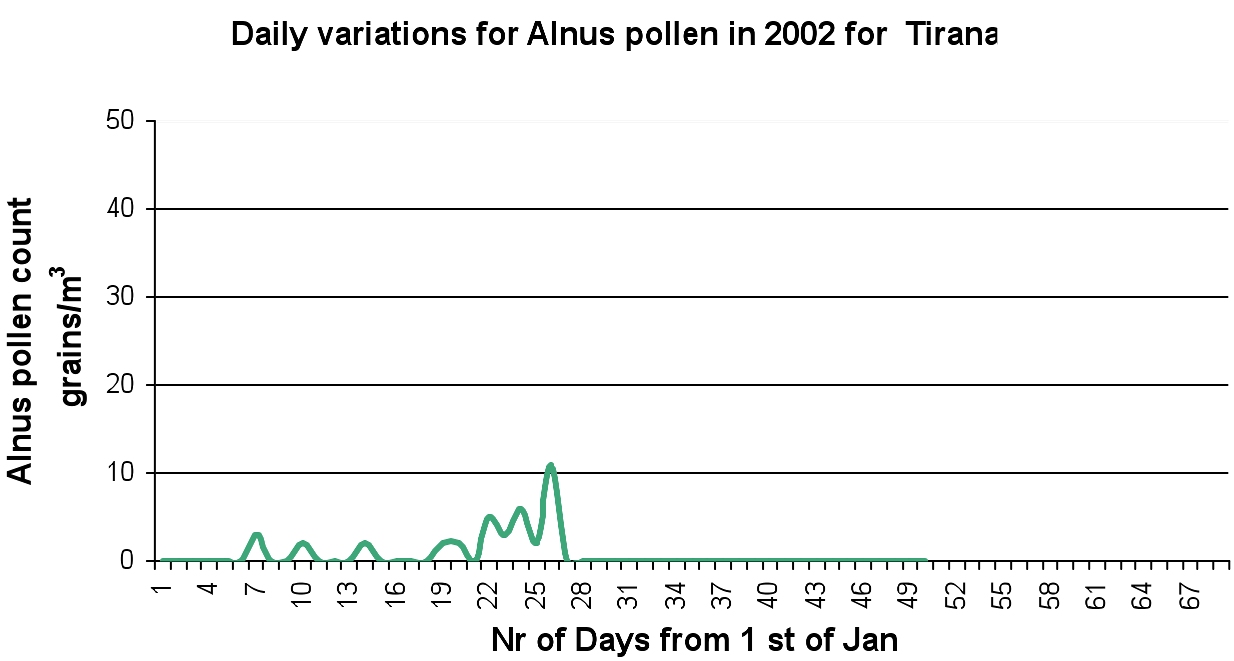


Fig. A11- d



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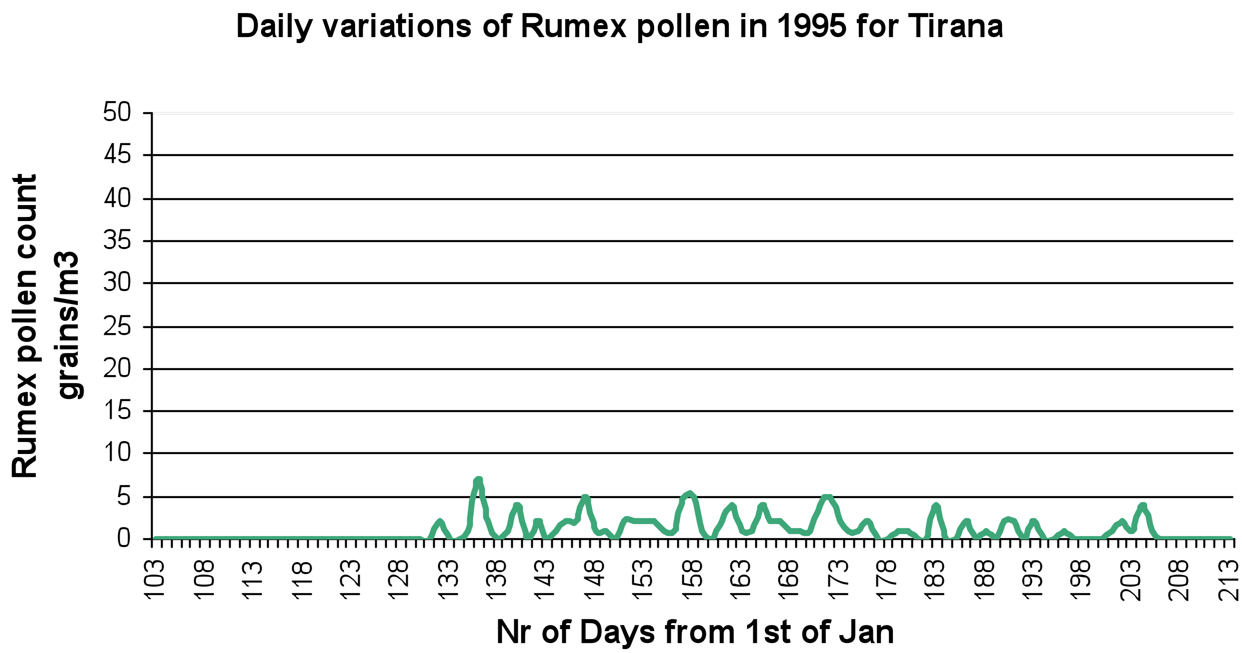


Fig. A12- b

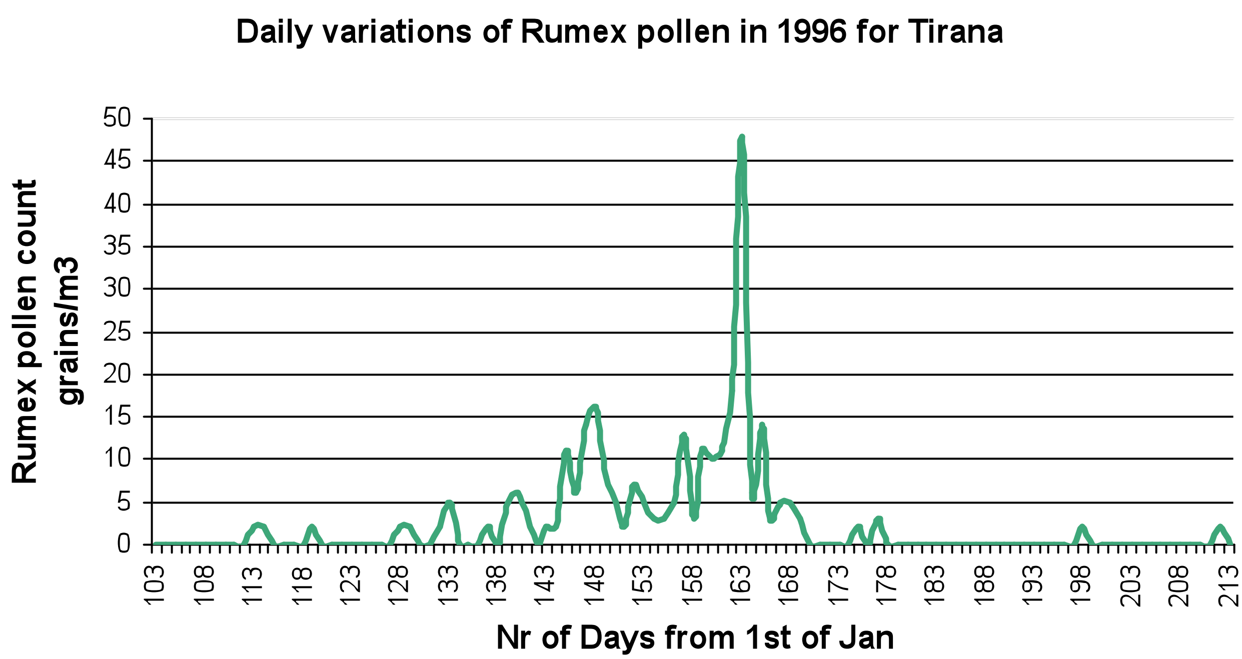


Fig. A12- c

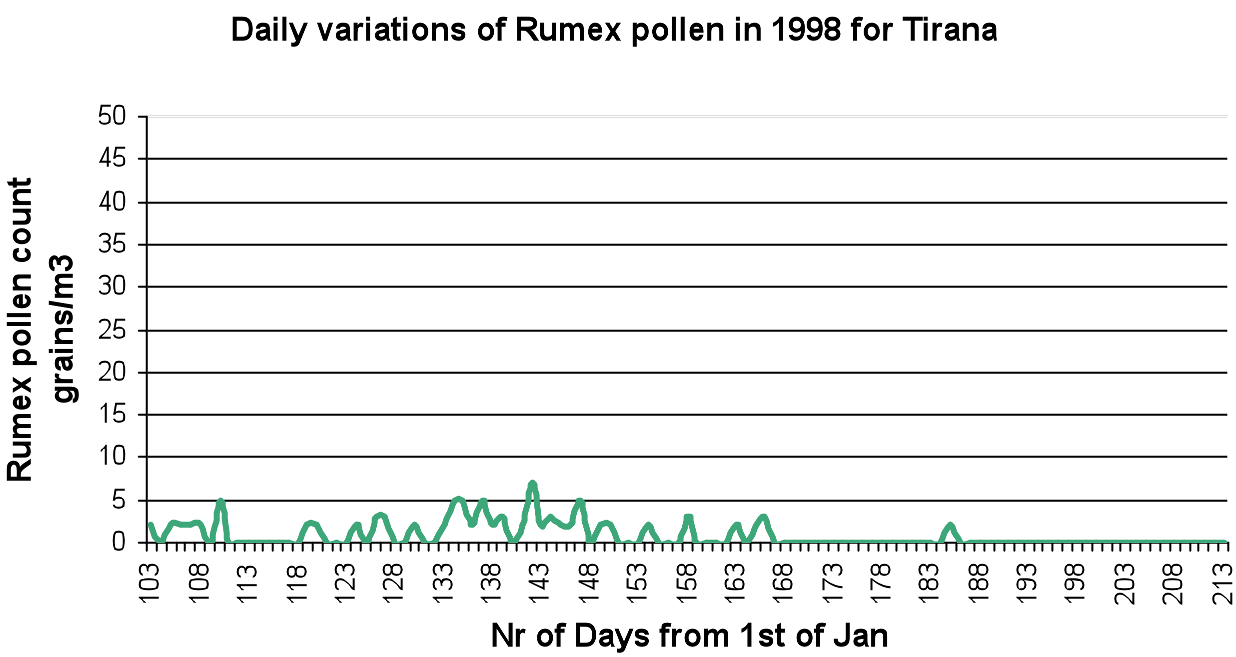
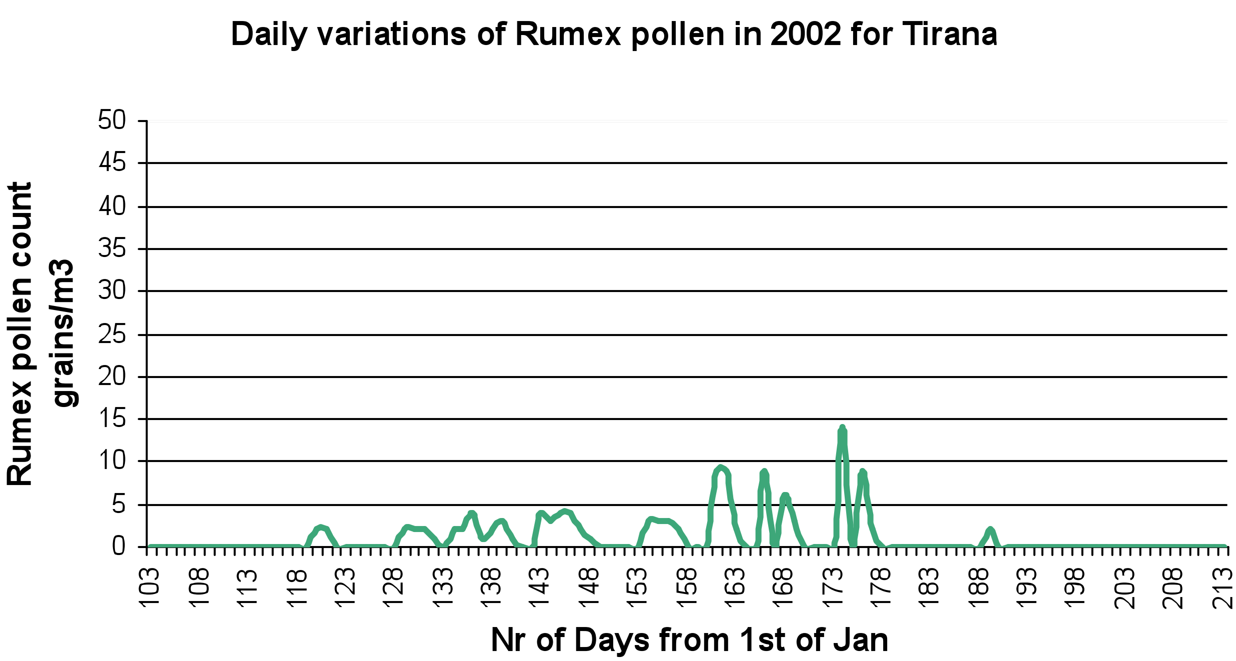


Fig. A12- d



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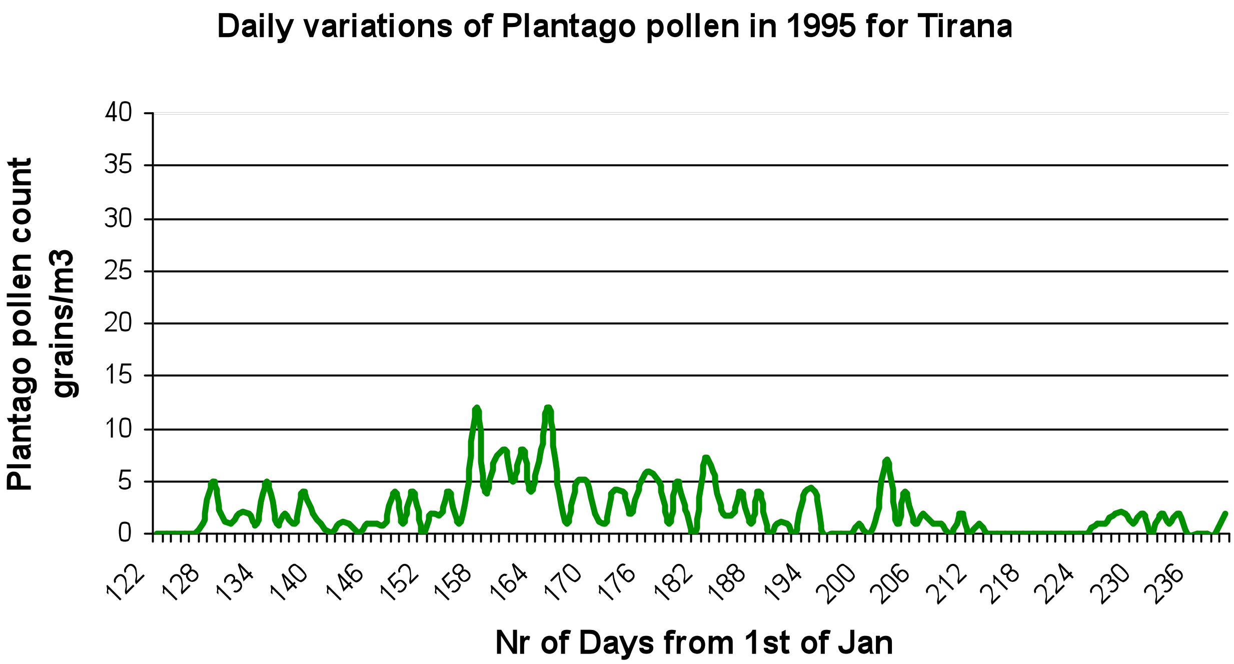


Fig. A13- b

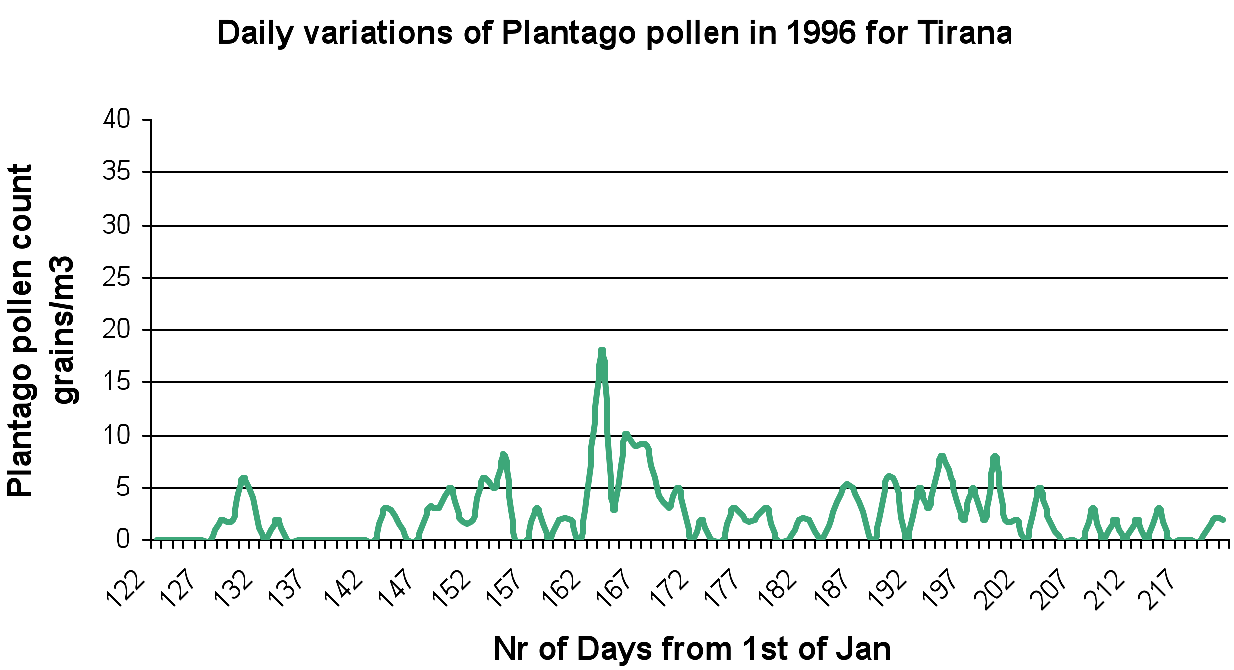
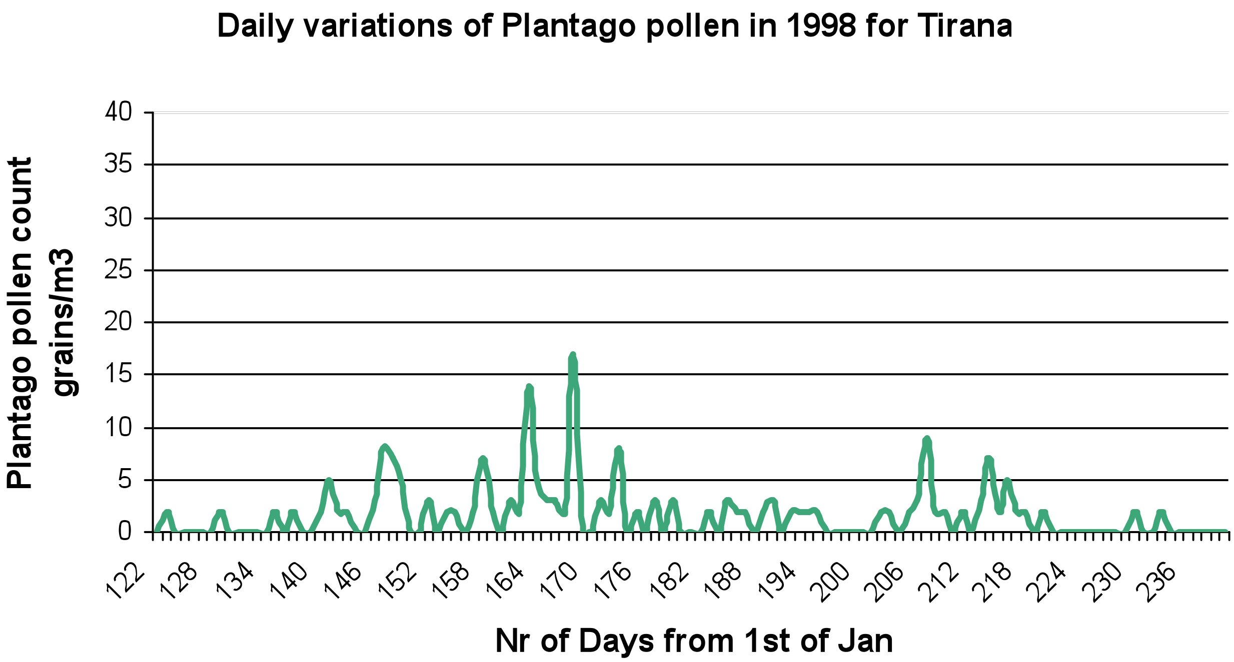


Fig. A13- c



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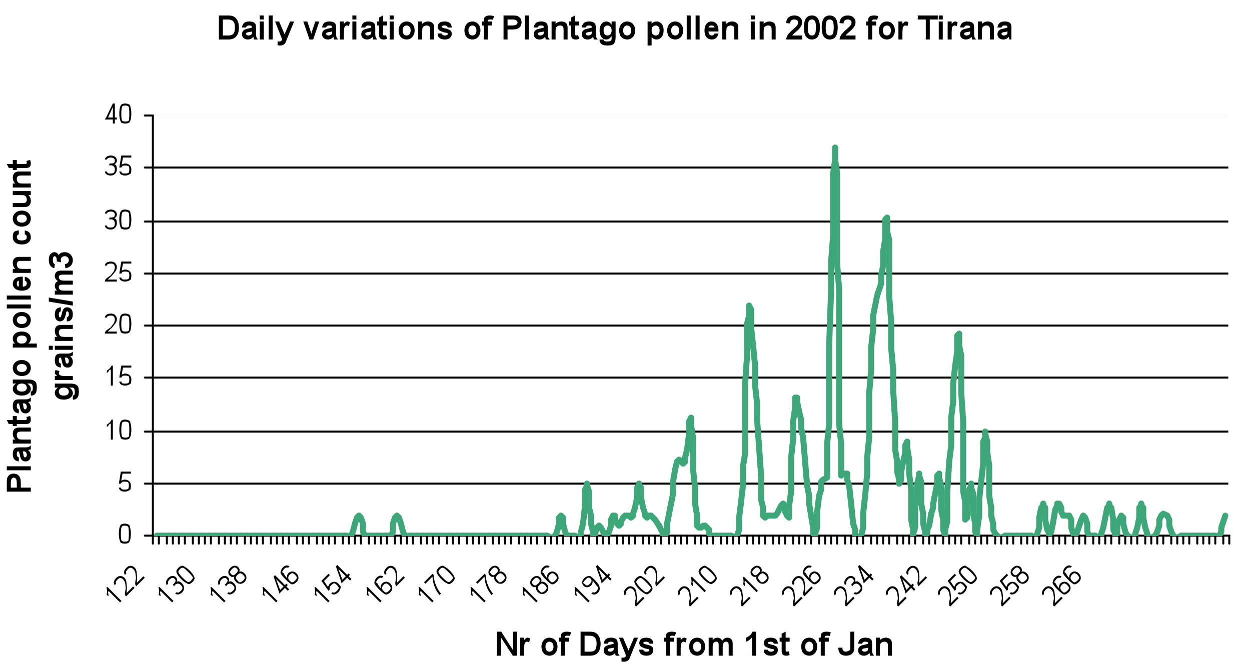


Fig. A14- a

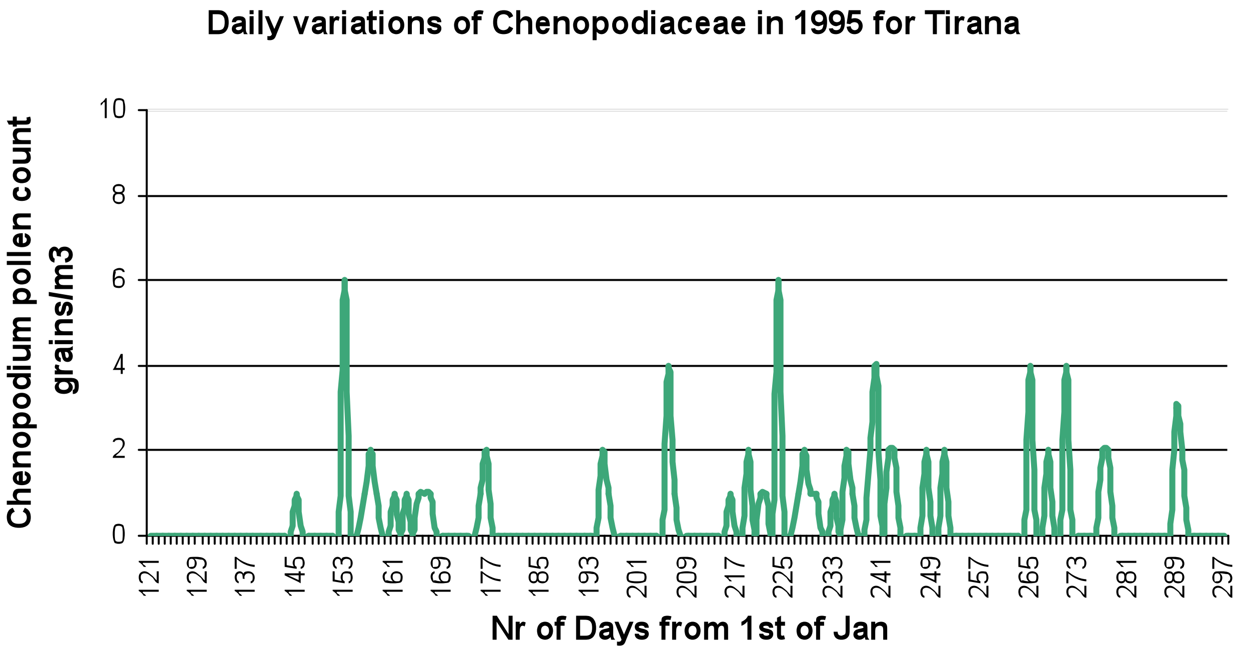


Fig. A14- b

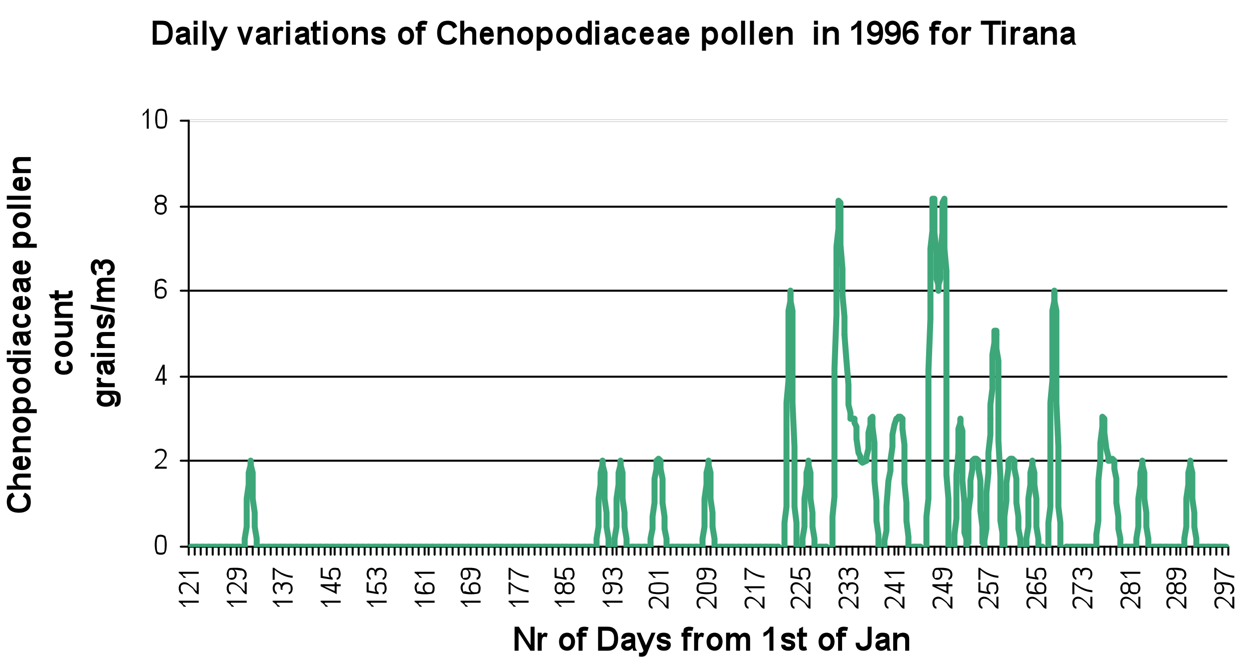
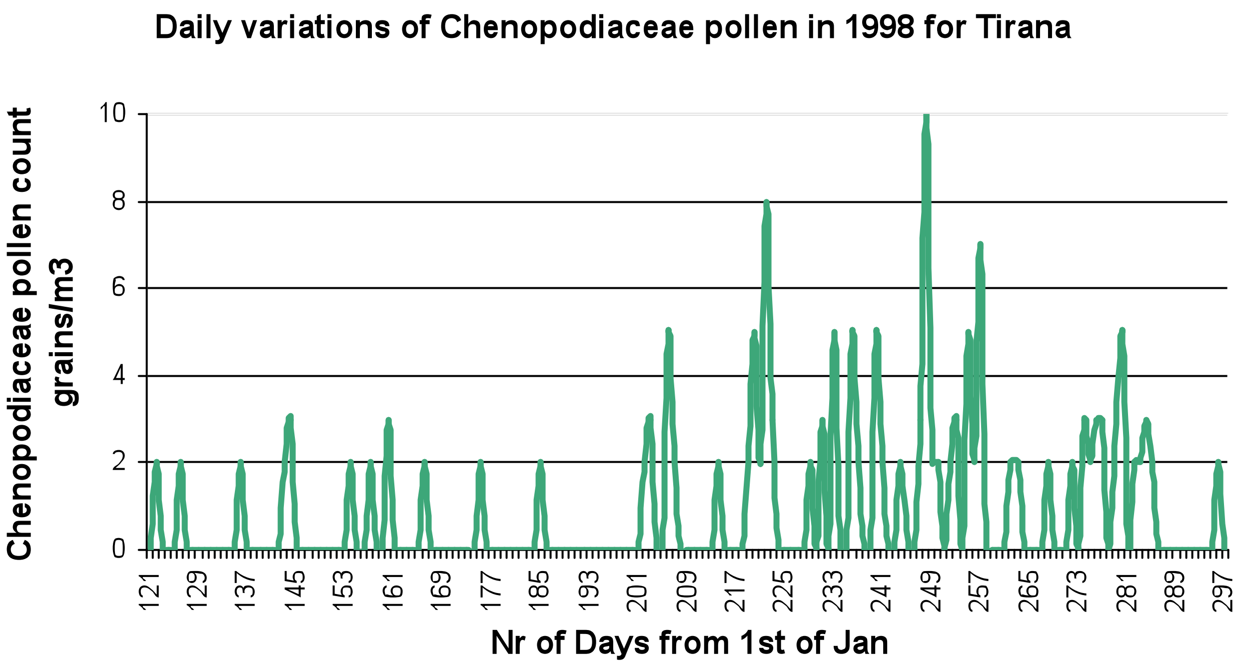


Fig. A14- c



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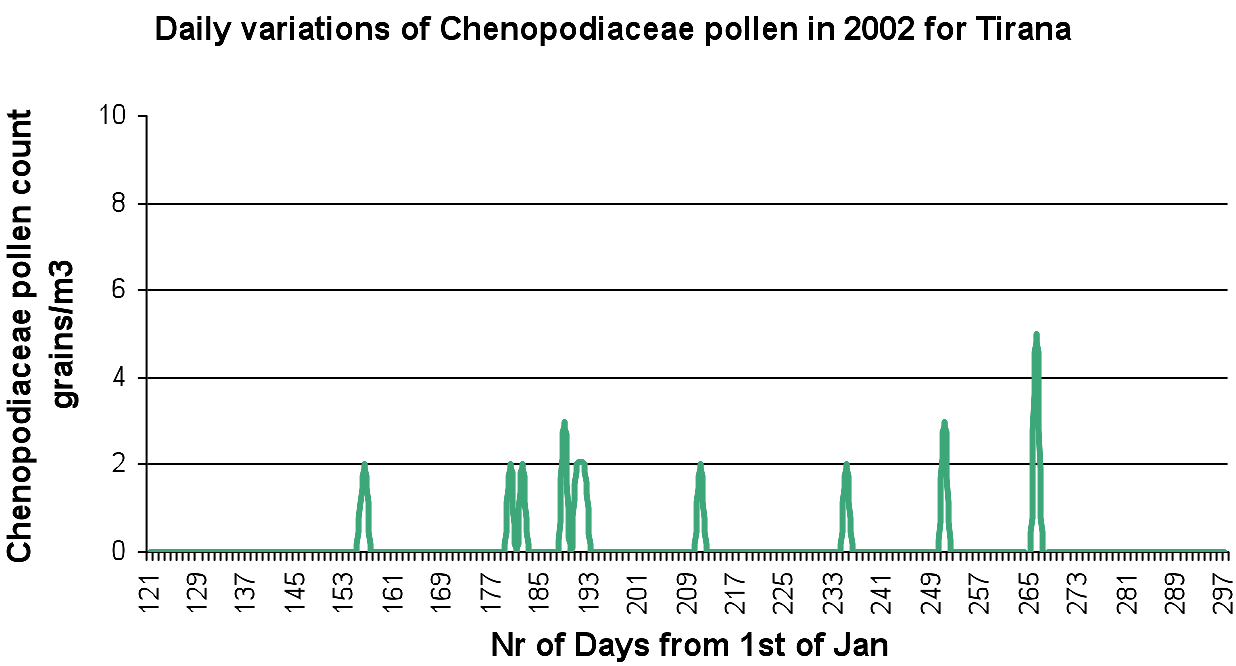


Fig.A15- a

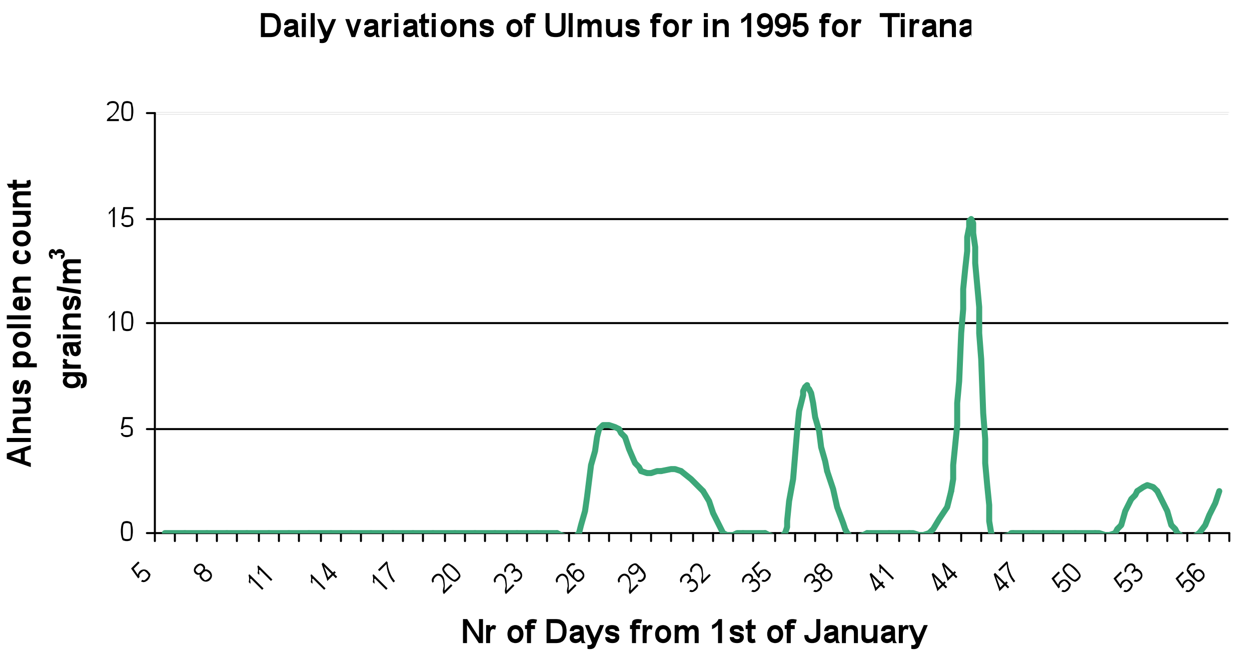


Fig.A15- b

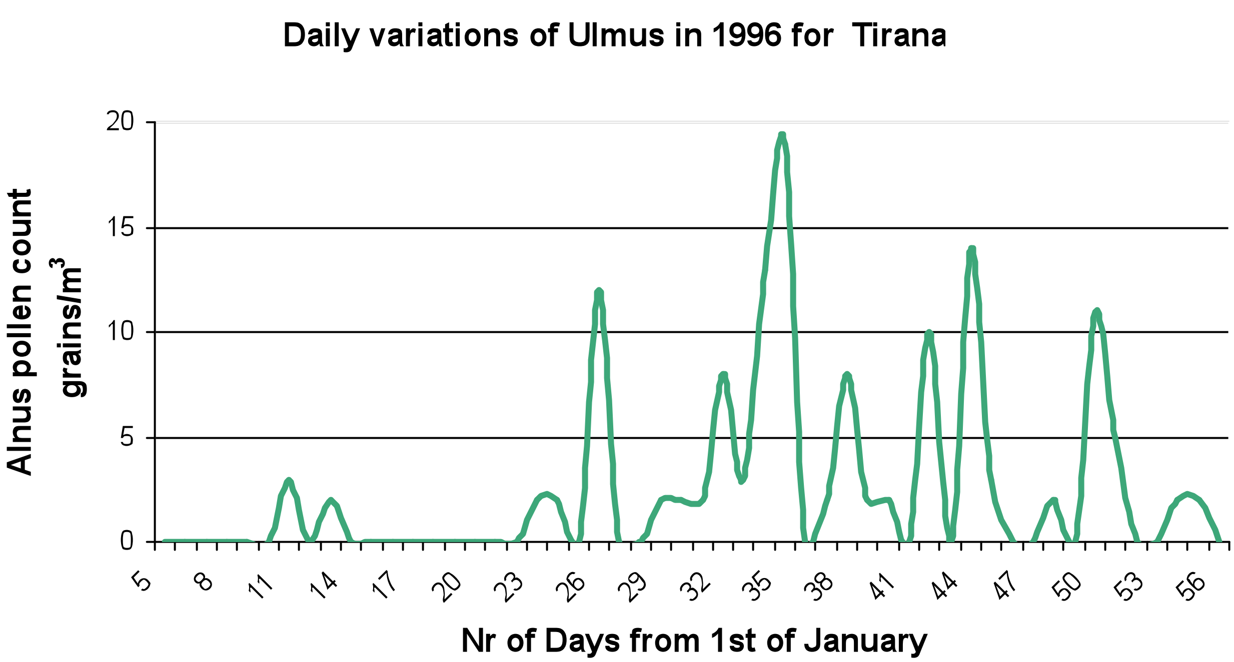


Fig. A15- c

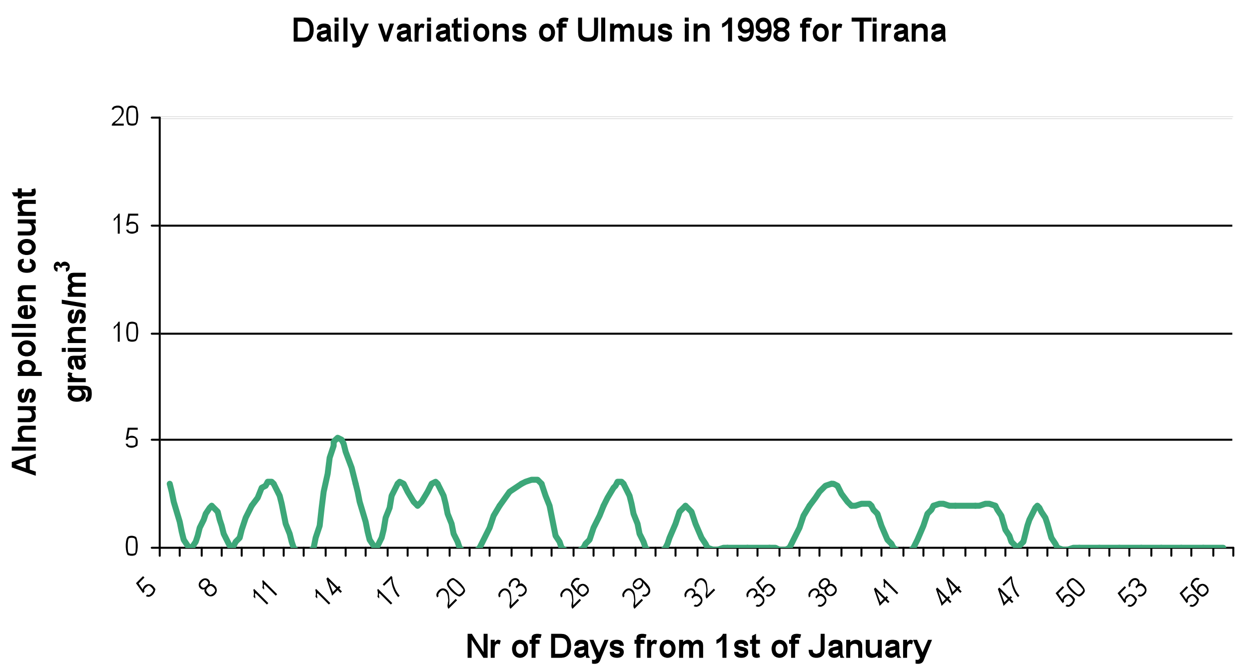
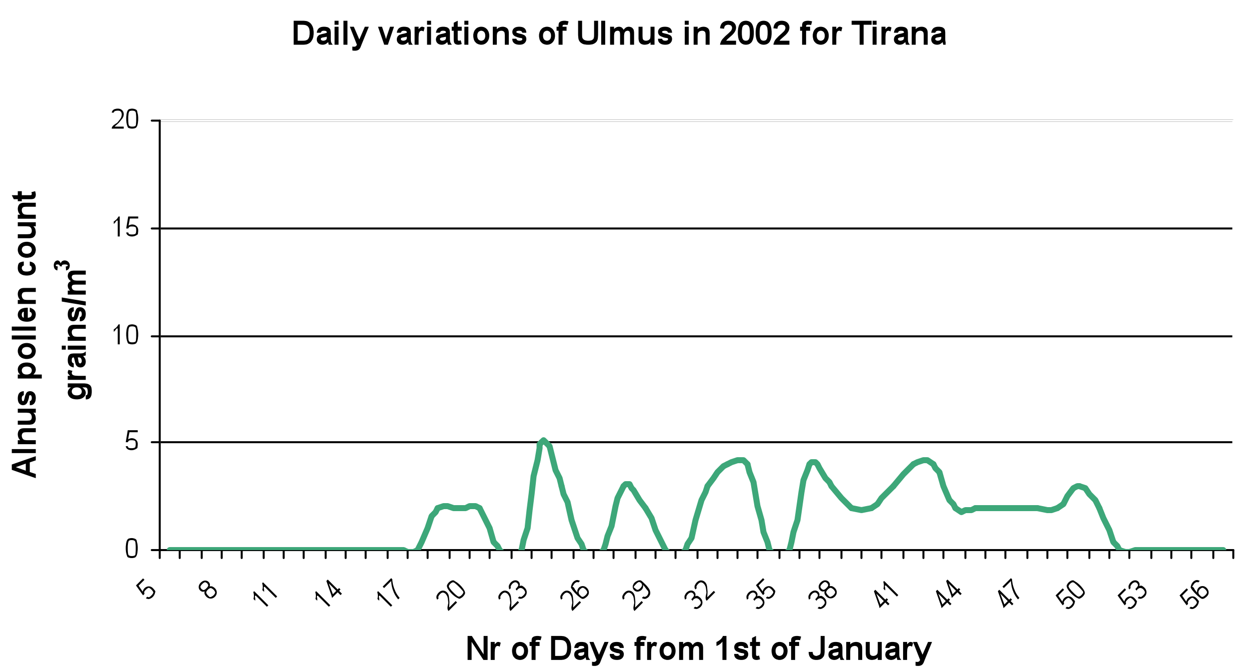


Fig. A15- d



APPENDIX B

Pearson correlations between grass and meteorological variables with 5% method in Tirana during the four years of study

*correlation significant at 0.05 level **correlation significant at the 0.01 level

	START	END	SEVERITY	LENGTH
rain days 1-10	-.163	.377	-.648	.270
rain days 11-20	.216	**.991***	-.499	.072
rain days 21-30	.043	.362	-.494	.062
rain days31-40	.396	.955*	-.345	-.117
rain days 41-50	.637	-.569	.739	-.795
rain days 51-60	.462	-.812	.850	-.691
rain days 61-70	.101	.709	-.622	.104
rain days 71-80	.572	-.752	.935	-.782
rain days 81-90	.533	-.249	.334	-.600
rain days 91-100	.442	-.839	.884	-.680
rain days 101-110	.490	.646	.108	-.299
rain days 111-120	-.734	.018	-.757	.732
rain days 121-130	.531	.361	.380	-.422
rain days 131-140	.427	.127	-.037	-.387
rain days 141-150	-.179	.716	-.818	.383
tmax 1-10	.858	.503	.382	-.704
tmax 11-20	.237	.376	.186	-.127
tmax21-30	-.816	-.561	-.319	.647
tmax31-40	-.874	-.559	-.307	.704
tmax41-50	-.800	.486	-.882	**.996****
tmax 51-60	-.509	.784	-.870	.730
tmax 61-70	**-.999****	.107	-.706	.969*
tmax 71-80	-.850	-.613	-.232	.665
tmax 81-90	-.476	-.926	.295	.204
tmax 91-100	.043	.742	-.281	.172
tmax 101-110	-.729	-.350	-.113	.620
tmax 111-120	-.240	-.948	.560	-.035
tmax 121-130	-.255	-.854	.545	.007
tmax 131-140	-.575	-.223	-.035	.505
tmax 141-150	.286	-.085	-.011	-.308
tmin 1-10	.911	.485	.298	-.762
tmin 11-20	-.103	.782	-.439	.327
tmin 21-30	-.189	-.942	.605	-.085
tmin 31-40	-.573	-.843	.225	.325
tmin 41-50	-.364	-.965*	.384	.082
tmin 51-60	-.835	.217	-.904	.889
tmin 61-70	-.999**	-.068	-.697	.970*

	START	END	SEVERITY	LENGTH
tmin 71-80	-.502	-.587	-.170	.328
tmin 81-90	-.211	-.633	.054	.026
tmin 91-100	-.355	-.814	.144	.117
tmin 101-110	-.850	-.163	-.364	.795
tmin 111-120	-.457	-.490	.227	.312
tmin 121-130	-.347	-.935	.310	.074
tmin 131-140	-.453	-.815	.358	.214
tmin 141-150	-.393	-.755	.057	.171
rain 1-20	.035	.849	-.715	.210
rain 21-40	.285	.849	-.519	-.038
rain41-60	.547	-.720	.816	-.749
rain 61-80	.631	.091	.176	-.599
rain 81-100	.469	-.542	.529	-.620
rain 101-120	-.055	.965	-.644	.332
rain 121-140	.915	.455	.310	-.775
rain 141-160	-.972*	.089	-.821	.988
tmax 1-20	.657	.487	.339	-.510
tmax 21-40	-.847	-.568	-.308	.675
tmax 41-60	-.670	.645	-.893	.849
tmax 61-80	-.988*	-.218	-.552	.916
tmax 81-100	-.275	.352	-.185	.374
tmax 101-120	-.646	-.580	.088	.472
tmax 121-140	-.453	-.601	.285	.275
tmax 141-160	.930	-.240	.893	-.990**
tmin 1-20	.710	.772	.024	-.480
tmin 21-40	-.446	-.935	.288	.172
tmin 41-60	-.663	-.079	-.660	.634
tmin 61-80	-.867	-.128	-.703	.822
tmin 81-100	-.281	-.886	.275	.023
tmin 101-120	-.991**	-.098	-.628	.953*
tmin 121-140	-.470	-.918	.325	.201
tmin 141-160	-.221	.342	-.668	.317
rain 1-30	.029	.734	-.685	.183
rain 31-60	.875	-.281	.754	-.947
rain 61-90	.557	-.073	.221	-.573
rain 91-120	.214	.976*	-.456	.069
rain 121-150	-.340	.690	-.902	.535
tmax 1-30	.563	.435	.337	-.432
tmax 31-60	-.827	.455	-.896	.951*
tmax 61-90	-.964*	-.352	-.444	.853
tmax 91-120	-.470	.029	-.108	.474
tmax 121-150	-.425	-.768	.374	.199
tmin 1-30	.896	.541	.296	-.732
tmin 31-60	-.772	-.345	-.508	.665

	START	END	SEVERITY	LENGTH
tmin 61-90	-.885	-.409	-.478	.759
tmin 91-120	-.937	-.180	-.471	.876
tmin 121-150	-.535	-.699	-.078	.328
rain 1-40	.132	.858	-.645	.116
rain 41-80	.665	-.391	.591	-.771
rain 81-120	.632	.336	.023	-.529
rain 121-160	-.752	.488	**-.990***	.885
tmax 1-40	.303	.336	.262	-.204
tmax 41-80	-.951*	.161	-.771	.988*
tmax 81-120	-.560	-.254	-.002	.481
tmax 121-160	-.037	-.701	.667	-.166
tmin 1-40	.977*	.138	.693	-.928
tmin 41-80	-.917	-.218	-.644	.846
tmin 81-120	-.794	-.647	-.213	.600
tmin 121-160	-.563	-.359	-.399	.454
rain 1-50	.233	.740	-.531	-.017
rain 51-100	.660	-.333	.532	-.749
rain 101-150	-.235	.916	-.869	.497
tmax 1-50	-.302	.575	-.404	.465
tmax 51-100	-.929	.114	-.679	.952*
tmax 101-150	-.523	-.667	.247	.326
tmin 1-50	.546	-.530	.595	-.693
tmin 51-100	-.906	-.327	-.553	.803
tmin 101-150	-.903	-.430	-.455	.770
rain mean 10-30	.184	.908	-.610	.079
rain mean 31-50	.883	.445	.256	-.746
rain mean 51-70	.619	.020	.214	-.608
rain mean 71-90	.578	-.606	.710	-.747
rain mean 91-110	.132	.299	.174	-.045
rain mean 111-130	.669	.357	.047	-.559
rain mean 131-150	-.642	.441	-.949	.763
tmax mean 10-30	-.285	-.036	.098	.272
tmax mean 31-50	-.965*	.139	-.790	.996*
tmax 51-70	-.876	.345	-.833	.967*
tmax 71-90	-.732	-.749	.005	.509
tmax 91-110	-.617	.221	-.394	.675
tmax 111-130	-.041	-.512	.577	-.107
tmax 131-150	-.371	-.958*	.353	.091
tmin 10-30	-.581	-.291	.001	.491
tmin 31-50	-.523	-.847	.103	.274
tmin 51-70	-.972*	.012	-.790	.966*
tmin 71-90	-.361	-.797	.121	.128
tmin 91-110	-.916	.132	-.674	.945
tmin 111-130	-.418	-.949	.336	.140

	START	END	SEVERITY	LENGTH
tmin 131-150	-.323	.126	-.603	.356
rain mean 10-40	.259	.958*	-.540	.020
rain mean 41-70	.533	-.077	.201	-.550
rain mean 71-100	.734	-.568	.882	-.890
rain mean 101-130	.353	.816	-.148	-.114
rain mean 131-160	-.830	.102	-.841	.851
tmax mean 10-40	-.710	-.287	-.130	.620
tmax mean 41-70	-.852	.391	-.847	.957*
tmax mean 71-100	-.788	-.374	-.166	.672
tmax mean 101-130	-.483	-.668	.285	.286
tmax mean 131-160	.345	-.824	.930	-.579
tmin mean 10-40	-.598	-.737	.192	.380
tmin mean 41-70	-.961*	-.081	-.740	.928
tmin mean 71-100	-.452	-.808	.084	.214
tmin 100-130	-.932	-.465	-.368	.788
tmin 131-160	-.301	.076	-.557	.320
rain mean 10-50	.438	.835	-.376	-.193
rain mean 51-90	.645	-.288	.478	-.722
rain mean 91-130	.412	.697	.013	-.207
rain mean 131-170	-.147	.860	-.568	.393
tmax mean 10-50	-.802	.007	-.426	.796
tmax mean 51-90	-.993**	-.208	-.576	.924
tmax mean 91-130	-.188	-.474	.444	.050
tmax mean 131-170	.433	-.256	.246	-.502
tmin mean 10-50	.629	-.449	.605	-.752
tmin 51-90	.194	.206	-.283	-.133
tmin 91-130	-.309	-.073	.103	.284
tmin 131-170	.120	.286	-.391	-.036
tmax cum 1-10	.843	.448	.437	-.706
tmax cum 11-20	.639	.453	.360	-.502
tmax cum 21-30	.539	.390	.361	-.422
tmax cum 31-40	.290	.244	.324	-.217
tmax cum 41-50	-.292	.491	-.318	.430
tmax cum 51-60	-.407	.654	-.579	.591
tmax cum 61-70	-.688	.465	-.689	.815
tmax cum 71-80	-.858	.226	-.675	.915
tmax cum 81-90	-.894	.114	-.625	.918
tmax cum 91-100	-.802	.250	-.623	.866
tmax cum 101-110	-.812	.160	-.557	.850
tmax cum 111-120	-.821	.093	-.514	.840
tmax cum 121-130	-.814	-.017	-.421	.801
tmax cum 131-140	-.796	-.038	-.386	.777
tmax cum 141-150	-.813	-.044	-.402	.793

	START	END	SEVERITY	LENGTH
tmin 1-50	.546	-.530	.595	-.693
tmin 51-100	-.906	-.327	-.553	.803
tmin 101-150	-.903	-.430	-.455	.770
rain mean 10-30	.184	.908	-.610	.079
rain mean 31-50	.883	.445	.256	-.746
rain mean 51-70	.619	.020	.214	-.608
rain mean 71-90	.578	-.606	.710	-.747
rain mean 91-110	.132	.299	.174	-.045
rain mean 111-130	.669	.357	.047	-.559
rain mean 131-150	-.642	.441	-.949	.763
tmax mean 10-30	-.285	-.036	.098	.272
tmax mean 31-50	-.965	.139	-.790	.996
tmax 51-70	-.876	.345	-.833	.967
tmax 71-90	-.732	-.749	.005	.509
tmax 91-110	-.617	.221	-.394	.675
tmax 111-130	-.041	-.512	.577	-.107
tmax 131-150	-.371	-.958	.353	.091
tmin 10-30	-.581	-.291	.001	.491
tmin 31-50	-.523	-.847	.103	.274
tmin 51-70	-.972	.012	-.790	.966
tmin 71-90	-.361	-.797	.121	.128
tmin 91-110	-.916	.132	-.674	.945
tmin 111-130	-.418	-.949	.336	.140
tmin 131-150	-.323	.126	-.603	.356
rain mean 10-40	.259	.958	-.540	.020
rain mean 41-70	.533	-.077	.201	-.550
rain mean 71-100	.734	-.568	.882	-.890
rain mean 101-130	.353	.816	-.148	-.114
rain mean 131-160	-.830	.102	-.841	.851
tmax mean 10-40	-.710	-.287	-.130	.620
tmax mean 41-70	-.852	.391	-.847	.957
tmax mean 71-100	-.788	-.374	-.166	.672
tmax mean 101-130	-.483	-.668	.285	.286
tmax mean 131-160	.345	-.824	.930	-.579
tmin mean 10-40	-.598	-.737	.192	.380
tmin mean 41-70	-.961	-.081	-.740	.928
tmin mean 71-100	-.452	-.808	.084	.214
tmin 100-130	-.932	-.465	-.368	.788
tmin 131-160	-.301	.076	-.557	.320
rain mean 10-50	.438	.835	-.376	-.193
rain mean 51-90	.645	-.288	.478	-.722
rain mean 91-130	.412	.697	.013	-.207
rain mean 131-170	-.147	.860	-.568	.393
tmax mean 10-50	-.802	.007	-.426	.796

	START	END	SEVERITY	LENGTH
tmax mean 51-90	-.993	-.208	-.576	.924
tmax mean 91-130	-.188	-.474	.444	.050
tmax mean 131-170	.433	-.256	.246	-.502
tmin mean 10-50	.629	-.449	.605	-.752
tmin 51-90	.194	.206	-.283	-.133
tmin 91-130	-.309	-.073	.103	.284
tmin 131-170	.120	.286	-.391	-.036
tmax cum 1-10	.843	.448	.437	-.706
tmax cum 11-20	.639	.453	.360	-.502
tmax cum 21-30	.539	.390	.361	-.422
tmax cum 31-40	.290	.244	.324	-.217
tmax cum 41-50	-.292	.491	-.318	.430
tmax cum 51-60	-.407	.654	-.579	.591
tmax cum 61-70	-.688	.465	-.689	.815
tmax cum 71-80	-.858	.226	-.675	.915
tmax cum 81-90	-.894	.114	-.625	.918
tmax cum 91-100	-.802	.250	-.623	.866
tmax cum 101-110	-.812	.160	-.557	.850
tmax cum 111-120	-.821	.093	-.514	.840
tmax cum 121-130	-.814	-.017	-.421	.801
tmax cum 131-140	-.796	-.038	-.386	.777
tmax cum 141-150	-.813	-.044	-.402	.793
tmax cum 1-20	.656	.496	.330	-.507
tmax cum 21-40	.316	.323	.280	-.219
tmax cum 41-60	-.413	.686	-.619	.606
tmax cum 61-80	-.864	.241	-.697	.925
tmax cum 81-100	-.809	.264	-.644	.877
tmax cum 101-120	-.829	.105	-.533	.851
tmax cum 121-140	-.805	-.029	-.403	.789
tmax cum 141 -160	-.773	-.050	-.352	.751
tmax cum 1-30	.533	.391	.357	-.415
tmax cum 31-60	-.438	.648	-.604	.620
tmax cum 61-90	-.903	.105	-.631	.924
tmax cum 91-120	-.830	.087	-.520	.847
tmax cum 121-150	-.822	-.049	-.408	.799
tmax cum 1-40	.316	.323	.280	-.219
tmax cum 41-80	-.864	.241	-.697	.925
tmax cum 81-120	-.829	.105	-.533	.851
tamx cum 121-160	-.773	-.050	-.352	.751
tamx cum 1-50	-.306	.552	-.385	.462
tamx cum 51-100	-.809	.264	-.644	.877
tamx cum 101-150	-.823	-.035	-.419	.805
rain cum 1-10	-.163	.377	-.648	.270
rain cum 11-20	.028	.845	-.719	.216

	START	END	SEVERITY	LENGTH
rain cum 21-30	.034	.733	-.681	.178
rain cum 31-40	.135	.856	-.642	.113
rain cum 41-50	.240	.736	-.524	-.026
rain cum 51-60	.498	.487	-.188	-.353
rain cum 61-70	.340	.584	-.376	-.168
rain cum 71-80	.557	.353	-.060	-.450
rain cum 81-90	.549	.250	-.006	-.472
rain cum 91-100	.578	.195	.056	-.516
rain cum 101-110	.648	.333	.040	-.546
rain cum 111-120	.566	.353	-.051	-.459
rain cum 121-130	.669	.419	.013	-.542
rain cum 131-140	.623	.376	-.009	-.509
rain cum 141-150	.467	.430	-.186	-.338
rain cum 1-20	-.144	.419	-.659	.264
rain cum 21-40	.135	.856	-.642	.113
rain cum 41-60	.498	.487	-.188	-.353
rain cum 61-80	.557	.353	-.060	-.450
rain cum 81-100	.578	.195	.056	-.516
rain cum 101-120	.566	.353	-.051	-.459
rain cum 121-140	.623	.376	-.009	-.509
rain cum 141-160	.421	.432	-.228	-.292
rain cum 161-180	.389	.429	-.254	-.262
rain cum 181-200	.345	.473	-.316	-.205
rain cum 1-30	.034	.733	-.681	.178
rain cum 31-60	.498	.487	-.188	-.353
rain cum 61-90	.549	.250	-.006	-.472
rain cum 91-120	.566	.353	-.051	-.459
rain cum 121-150	.467	.430	-.186	-.338
rain cum 151-180	.389	.429	-.254	-.262
rain cum 1-40	.135	.856	-.642	.113
rain cum 41-80	.557	.353	-.060	-.450
rain cum 81-120	.566	.353	-.051	-.459
rain cum 121-160	.421	.432	-.228	-.292
rain cum 161-200	.421	.432	-.228	-.292
rain cum 201-240	.345	.473	-.316	-.205
rain cum 1-50	.240	.736	-.524	-.026
rain cum 51-100	.578	.195	.056	-.516
rain cum 101-150	.467	.430	-.186	-.338
rain cum 151-200	.345	.473	-.316	-.205

APPENDIX B1

Pearson correlation between meteorological variables and peak value, start and end of peak period for Grass in Tirana

*correlation significant at 0.05 level **correlation significant at the 0.01 level

		Start day of Peak value	Start of peak period	End of peak period
rain days 1-10	Pearson Correlation	.573	.097	.175
rain days 11-20	Pearson Correlation	.125	-.469	-.253
rain days 20-30	Pearson Correlation	.731	.267	-.028
rain days30-40	Pearson Correlation	.256	-.311	-.430
rain days 40-50	Pearson Correlation	.717	.997(**)	-.601
rain days 50-60	Pearson Correlation	.408	.896	-.425
rain days 60-70	Pearson Correlation	.616	-.007	-.105
rain days 70-80	Pearson Correlation	.370	.864	-.541
rain days 80-90	Pearson Correlation	.928	.909	-.499
rain days 90-100	Pearson Correlation	.318	.848	-.408
rain days 100-110	Pearson Correlation	-.117	-.339	-.530
rain days 110-120	Pearson Correlation	.006	-.211	.749
rain days 120-130	Pearson Correlation	-.216	-.216	-.564
rain days 130-140	Pearson Correlation	.956(*)	.665	-.403
rain days 140-150	Pearson Correlation	.387	-.238	.171
Tmax 1-10	Pearson Correlation	.364	.166	-.880
Tmax 10-20	Pearson Correlation	-.496	-.490	-.276
Tmax20-30	Pearson Correlation	-.322	-.091	.842
Tmax30-40	Pearson Correlation	-.498	-.224	.893
Tmax 41-50	Pearson Correlation	-.633	-.936	.774
Tmax 50-60	Pearson Correlation	-.429	-.905	.474
Tmax 61-70	Pearson Correlation	-.806	-.856	.931
Tmax 70-80	Pearson Correlation	-.536	-.209	.870
Tmax 80-90	Pearson Correlation	-.380	.190	.505
Tmax 90-100	Pearson Correlation	-.438	-.732	-.089
tmax 100-110	Pearson Correlation	-.965(*)	-.617	.719
Tmax 110-120	Pearson Correlation	-.409	.250	.265
Tmax 120-130	Pearson Correlation	-.569	.083	.270
Tmax 130-140	Pearson Correlation	-.986(*)	-.666	.556
Tmax 140-150	Pearson Correlation	.891	.714	-.254
tmin 1-10	Pearson Correlation	.736	.435	-.919
Tmin 10-20	Pearson Correlation	-.477	-.822	.057
Tmin 20-30	Pearson Correlation	-.402	.266	.212
Tmin 30-40	Pearson Correlation	-.591	-.026	.594
Tmin 40-50	Pearson Correlation	-.256	.327	.398
Tmin 50-60	Pearson Correlation	-.215	-.506	.836
Tmin 60-70	Pearson Correlation	-.667	-.671	.997(**)

Tmin 70-80	Pearson Correlation	.145	.317	.540
Tmin 80-90	Pearson Correlation	.397	.591	.255
Tmin 90-100	Pearson Correlation	.113	.477	.397
Tmin 100-110	Pearson Correlation	-.960(*)	-.764	.836
Tmin 110-120	Pearson Correlation	-.895	-.410	.450
Tmin 120-130	Pearson Correlation	-.079	.429	.386
Tmin 130-140	Pearson Correlation	-.666	-.059	.467
Tmin 140-150	Pearson Correlation	.135	.445	.435
rain 1-20	Pearson Correlation	.443	-.224	-.050
rain 20-40	Pearson Correlation	.587	-.060	-.300
rain40-60	Pearson Correlation	.552	.957(*)	-.510
rain 60-80	Pearson Correlation	**.998(**)**	.772	-.608
rain 80-100	Pearson Correlation	.773	.970(*)	-.428
rain 100-120	Pearson Correlation	-.151	-.709	.014
rain 120-140	Pearson Correlation	.770	.477	-.921
rain 140-160	Pearson Correlation	-.551	-.684	.967(*)
tmax 1-20	Pearson Correlation	-.007	-.122	-.690
tmax 20-40	Pearson Correlation	-.414	-.156	.870
tmax 40-60	Pearson Correlation	-.545	-.940	.638
tmax 60-80	Pearson Correlation	-.748	-.630	.988(*)
tmax 80-100	Pearson Correlation	-.821	-.830	.235
tmax 100-120	Pearson Correlation	-.873	-.392	.647
tmax 120-140	Pearson Correlation	-.842	-.306	.452
tmax 140-160	Pearson Correlation	.523	.748	-.921
tmin 1-20	Pearson Correlation	.434	.005	**-.990**
tmin 20-40	Pearson Correlation	-.273	.274	.480
tmin 40-60	Pearson Correlation	.107	-.066	.685
tmin 60-80	Pearson Correlation	-.218	-.304	.882
tmin 80-100	Pearson Correlation	.093	.529	.324
tmin 100-120	Pearson Correlation	-.766	-.716	.985(*)
tmin 120-140	Pearson Correlation	-.454	.138	.497
tmin 140-160	Pearson Correlation	.533	.076	.234
rain 1-30	Pearson Correlation	.548	-.086	-.035
rain 30-60	Pearson Correlation	.795	.936	-.852
rain 60-90	Pearson Correlation	.975(*)	.837	-.528
rain 90-120	Pearson Correlation	.038	-.517	-.254
rain 120-150	Pearson Correlation	.236	-.365	.331
tmax 1-30	Pearson Correlation	-.151	-.211	-.598
tmax 30-60	Pearson Correlation	-.616	-.914	.804
tmax 60-90	Pearson Correlation	-.732	-.529	.969(*)
tmax 90-120	Pearson Correlation	-.962(*)	-.777	.441
tmax 120-150	Pearson Correlation	-.713	-.111	.434
tmin 1-30	Pearson Correlation	.614	.317	-.911
tmin 30-60	Pearson Correlation	-.101	-.068	.798
tmin 60-90	Pearson Correlation	-.354	-.225	.906

tmin 90-120	Pearson Correlation	-.885	-.728	.929
tmin 120-150	Pearson Correlation	.020	.295	.573
rain 1-40	Pearson Correlation	.500	-.165	-.147
rain 40-80	Pearson Correlation	.859	.988(*)	-.631
rain 80-120	Pearson Correlation	.973(*)	.605	-.620
rain 121-160	Pearson Correlation	-.246	-.671	.740
tmax 1-40	Pearson Correlation	-.451	-.418	-.340
tmax 40-80	Pearson Correlation	-.744	-.849	.936
tmax 80-120	Pearson Correlation	-.979(*)	-.639	.542
tmax 120-160	Pearson Correlation	-.577	.045	.041
tmin 1-40	Pearson Correlation	.503	.515	-.983(*)
tmin 40-80	Pearson Correlation	-.340	-.343	.932
tmin 80-120	Pearson Correlation	-.384	-.073	.820
tmin 120-160	Pearson Correlation	.180	.183	.595
rain 1-50	Pearson Correlation	.668	.045	-.239
rain 50-100	Pearson Correlation	.894	.973(*)	-.626
rain 100-150	Pearson Correlation	.037	-.605	.207
tmax 1-50	Pearson Correlation	-.720	-.909	.258
tmax 50-100	Pearson Correlation	-.838	-.876	.911
tmax 100-150	Pearson Correlation	-.813	-.266	.527
tmin 1-50	Pearson Correlation	.781	**.990(*)**	-.506
tmin 50-100	Pearson Correlation	-.356	-.283	.924
tmin 100-150	Pearson Correlation	-.419	-.259	.922
rain mean 10-30	Pearson Correlation	.462	-.206	-.204
rain mean 30-50	Pearson Correlation	.840	.520	-.885
rain mean 50-70	Pearson Correlation	.994(**)	.809	-.594
rain mean 70-90	Pearson Correlation	.703	.993(**)	-.540
rain mean 90-110	Pearson Correlation	-.601	-.541	-.170
rain mean 110-130	Pearson Correlation	.968(*)	.598	-.658
tmax mean 10-30	Pearson Correlation	-.900	-.645	.256
tmax mean 30-50	Pearson Correlation	-.699	-.811	.953(*)
tmax 50-70	Pearson Correlation	-.709	-.920	.853
tmax 70-90	Pearson Correlation	-.599	-.133	.752
tmax 90-110	Pearson Correlation	-.944	-.925	.585
tmax 110-130	Pearson Correlation	-.682	-.141	.034
tmax 130-150	Pearson Correlation	-.207	.352	.407
tmin 10-30	Pearson Correlation	-.977(*)	-.621	.566
tmin 30-50	Pearson Correlation	-.153	.277	.560
tmin 50-70	Pearson Correlation	-.501	-.605	.973(*)
tmin 70-90	Pearson Correlation	.126	.473	.404
tmin 90-110	Pearson Correlation	-.848	-.890	.897
tmin 110-130	Pearson Correlation	-.298	.275	.450
tmin 130-150	Pearson Correlation	.478	.145	.344
rain mean 10-40	Pearson Correlation	.390	-.264	-.285

rain mean 40-70	Pearson Correlation	.970(*)	.829	-.503
rain mean 70-100	Pearson Correlation	.604	.949	-.704
rain mean 100-130	Pearson Correlation	-.113	-.479	-.395
rain mean 130-160	Pearson Correlation	-.164	-.400	.837
tmax mean 10-40	Pearson Correlation	-.982(*)	-.663	.697
tmax mean 40-70	Pearson Correlation	-.692	-.930	.829
tmax mean 70-100	Pearson Correlation	-.943	-.605	.782
tmax mean 100-130	Pearson Correlation	-.807	-.250	.486
tmax mean 130-160	Pearson Correlation	-.066	.561	-.324
tmin mean 10-40	Pearson Correlation	-.747	-.200	.609
tmin mean 40-70	Pearson Correlation	-.441	-.505	.967(*)
tmin mean 70-100	Pearson Correlation	.009	.379	.492
tmin 100-130	Pearson Correlation	-.650	-.397	.943
tmin 130-160	Pearson Correlation	.502	.198	.324
rain mean 10-50	Pearson Correlation	.641	.026	-.453
rain mean 50-90	Pearson Correlation	.917	.957(*)	-.612
rain mean 90-130	Pearson Correlation	-.165	-.423	-.454
rain mean 130-170	Pearson Correlation	-.396	-.830	.102
tmax mean 10-50	Pearson Correlation	-.971(*)	-.862	.781
tmax mean 50-90	Pearson Correlation	-.717	-.616	.994(**)
tmax mean 90-130	Pearson Correlation	-.787	-.275	.179
tmax mean 130-170	Pearson Correlation	.906	.870	-.396
tmin mean 10-50	Pearson Correlation	.829	.993(**)	-.593
tmin 50-90	Pearson Correlation	.850	.482	-.173
tmin 90-130	Pearson Correlation	-.911	-.636	.282
tmin 130-170	Pearson Correlation	.796	.377	-.101

APPENDIX C:
Pearson correlations between Olea and meteorological variables with Method 1 in Tirana during the four years of study
*correlation significant at 0.05 level **correlation significant at the 0.01 level

	START	END	SEVERITY	LENGTH
rain days 1-10	.507**	.778	.860	.931
rain days 11-20	-.062	-.046	-.097	-.019
rain days 21-30	.589	.837	.849	.953*
rain days31-40	.090	.049	-.161	-.008
rain days 41-50	.855	.695	.072	.372
rain days 51-60	.603	.414	-.092	.114
rain days 61-70	.421	.632	.642	.747
rain days 71-80	.572	.317	-.275	-.038
rain days 81-90	.964*	.957*	.466	.757
rain days 91-100	.525	.314	-.179	.011
rain days 101-110	-.169	-.410	-.743	-.604
rain days 111-120	-.105	.292	.923	.687
rain days 121-130	-.192	-.513	-.919	-.778
rain days 131-140	.895	.989*	.640	.897
rain days 141-150	.173	.460	.710	.696
tmax 1-10	.347	.052	-.614	-.296
tmax 11-20	-.490	-.744	-.896	-.885
tmax21-30	-.291	-.010	.613	.313
tmax31-40	-.459	-.204	.469	.128
tmax41-50	-.787	-.519	.233	-.109
tmax 51-60	-.623	-.418	.125	-.099
tmax 61-70	-.884	-.629	.197	-.211
tmax 71-80	-.478	-.253	.392	.055
tmax 81-90	-.219	-.173	.109	-.085
tmax 91-100	-.541	-.638	-.574	-.621
tmax 101-110	-.901	-.857	-.280	-.634
tmax 111-120	-.206	-.298	-.221	-.343
tmax 121-130	-.372	-.499	-.395	-.543
tmax 131-140	-.924	-.957	-.494	-.802
tmax 141-150	.860	.989*	.732	.937
tmin 1-10	.693	.489	-.225	.158
tmin 11-20	-.606	-.634	-.440	-.539
tmin 21-30	-.193	-.309	-.275	-.380
tmin 31-40	-.440	-.402	-.025	-.278
tmin 41-50	-.083	-.059	.122	-.021
tmin 51-60	-.359	.038	.783	.485
tmin 61-70	-.730	-.418	.429	.023
tmin 71-80	.179	.441	.791	.652
tmin 81-90	.458	.642	.736	.724

	START	**END**	**SEVERITY**	**LENGTH**
tmin 91-100	.219	.372	.565	.471
tmin 101-110	-.953*	-.825	-.118	-.512
tmin 111-120	-.770	-.860	-.534	-.791
tmin 121-130	.073	.147	.318	.203
tmin 131-140	-.496	-.545	-.267	-.491
tmin 141-150	.221	.406	.640	.536
rain 1-20	.228	.431	.516	.577
rain 21-40	.393	.509	.380	.540
rain41-60	.725	.546	-.021	.231
rain 61-80	.971*	.965*	.437	.766
rain 81-100	.876	.826	.350	.603
rain 101-120	-.344	-.276	-.098	-.142
rain 121-140	.731	.533	-.190	.199
rain 141-160	-.655	-.305	.540	.156
tmax 1-20	-.012	-.321	-.818	-.611
tmax 21-40	-.377	-.110	.539	.218
tmax 41-60	-.721	-.480	.181	-.109
tmax 61-80	-.771	-.505	.313	-.099
tmax 81-100	-.852	-.939	-.655	-.850
tmax 101-120	-.758	-.749	-.274	-.589
tmax 121-140	-.699	-.785	-.478	-.726
tmax 141-160	.655	.305	-.525	-.158
tmin 1-20	.333	.164	-.339	-.061
tmin 21-40	-.116	-.051	.204	.033
tmin 41-60	.016	.399	.956	.757
tmin 61-80	-.295	.087	.813	.506
tmin 81-100	.226	.326	.447	.375
tmin 101-120	-.813	-.540	.296	-.120
tmin 121-140	-.286	-.266	.012	-.190
tmin 141-160	.376	.699	.934	.928

rain 1-30	.345	.575	.649	.723
rain 31-60	.901	.665	-.124	.261
rain 61-90	.973*	.985*	.497	.800
rain 91-120	-.137	-.150	-.201	-.134
rain 121-150	.020	.341	.726	.641
tmax 1-30	-.144	-.455	-.878	-.719
tmax 31-60	-.769	-.484	.287	-.061
tmax 61-90	-.725	-.479	.299	-.101
tmax 91-120	-.940	**-.998****	-.591	-.865
tmax 121-150	-.544	-.619	-.359	-.580
tmin 1-30	.570	.339	-.356	.007
tmin 31-60	-.132	.217	.832	.573
tmin 61-90	-.362	-.040	.663	.336

	START	END	SEVERITY	LENGTH
tmin 91-120	-.895	-.697	.082	-.331
tmin 121-150	.085	.314	.678	.513
rain 1-40	.291	.462	.465	.564
rain 41-80	.951*	.838	.214	.540
rain 81-120	.897	.906	.409	.733
rain 121-160	-.432	-.065	.646	.369
tmax 1-40	-.432	-.710	-.924	-.886
tmax 41-80	-.840	-.558	.279	-.123
tmax 81-120	-.910	-.951*	-.506	-.808
tmax 121-160	-.379	-.611	-.675	-.754
tmin 1-40	.566	.219	-.600	-.222
tmin 41-80	-.394	-.033	.723	.387
tmin 81-120	-.327	-.086	.507	.207
tmin 121-160	.155	.481	.915	.759
rain 1-50	.481	.641	.542	.696
rain 51-100	.969*	.876	.265	.593
rain 101-150	-.191	.032	.357	.279
tmax 1-50	-.810	-.830	-.492	-.685
tmax 51-100	-.912	-.677	.135	-.271
tmax 101-150	-.669	-.714	-.356	-.623
tmin 1-50	.891	.804	.264	.543
tmin 51-100	-.384	-.044	.688	.354
tmin 101-150	-.418	-.110	.605	.264
rain mean 10-30	.254	.389	.354	.465
rain mean 31-50	.791	.632	-.064	.323
rain mean 51-70	.980*	.973*	.444	.769
rain mean 71-90	.841	.705	.127	.407
rain mean 91-110	-.584	-.822	-.895	-.931
rain mean 111-130	.894	.883	.358	.694
rain mean 131-150	-.179	.208	.818	.608
tmax mean 10-30	-.843	-.987*	-.747	-.953*
tmax mean 31-50	-.797	-.495	.352	-.049
tmax 51-70	**-.999****	-.567	.231	-.144
tmax 71-90	-.490	-.361	.165	-.141
tmax 91-110	-.985*	-.941	-.381	-.702
tmax 111-130	-.513	-.759	-.793	-.889
tmax 131-150	-.041	.002	.190	.052
tmin 10-30	-.903	-.936	-.477	-.786
tmin 31-50	-.038	.115	.448	.266
tmin 51-70	-.595	-.236	.599	.222
tmin 71-90	.226	.388	.589	.495
tmin 91-110	-.923	-.696	.107	-.296
tmin 111-130	-.131	-.091	.138	-.027

	START	END	SEVERITY	LENGTH
tmin 131-150	.357	.697	.990**	.946
rain mean 10-40	.190	.266	.174	.299
rain mean 41-70	.966	.989*	.522	.817
rain mean 71-100	.768	.519	-.187	.130
rain mean 101-130	-.220	-.370	-.561	-.468
rain mean 131-160	-.289	.111	.836	.547
tmax mean 10-40	-.927	-.893	-.323	-.674
tmax mean 41-70	-.827	-.560	.224	-.142
tmax mean 71-100	-.885	-.804	-.179	-.549
tmax mean 101-130	-.657	-.722	-.399	-.651
tmax mean 131-160	.162	-.120	-.528	-.418
tmin mean 10-40	-.606	-.596	-.184	-.465
tmin mean 41-70	-.519	-.155	.657	.292
tmin mean 71-100	.110	.281	.558	.420
tmin mean 100-130	-.623	-.378	.357	-.022
Tmin mean 131-160	.392	.723	.991**	.957*
rain mean 10-50	.467	.517	.255	.471
rain mean 51-90	.978*	.905	.312	.638
rain mean 91-130	-.233	-.444	-.702	-.596
rain mean 131-170	-.556	-.528	-.285	-.389
tmax mean 10-50	-.992**	-.877	-.188	-.570
tmax mean 51-90	-.746	-.466	.357	-.052
tmax mean 91-130	-.637	-.835	-.738	-.894
tmax mean 131-170	.931	.970*	.564	.820
tmin mean 10-50	.930	.821	.221	.532
tmin 51-90	.750	.941	**.997****	**.977****
tmin 91-130	-.849	-.987	-.732	-.946
tmin 131-170	.674	.895	.831	.968*
tmax cum 1-10	.285	-.034	-.696	-.391
tmax cum 11-20	-.045	-.361	-.846	-.650
tmax cum 21-30	-.179	-.496	-.905	-.759
tmax cum 31-40	-.445	-.737	-.952*	-.922
tmax cum 41-50	-.833	-.881	-.564	-.759
tmax cum 51-60	-.804	-.747	-.309	-.531
tmax cum 61-70	-.913	-.760	-.107	-.433
tmax cum 71-80	-.945	-.744	.022	-.365
tmax cum 81-90	-.949	-.747	.034	-.366
tmax cum 91-100	-.968	-.804	-.082	-.455
tmax cum 101-110	-.984*	-.835	-.116	-.497
tmax cum 111-120	-.988	-.847	-.130	-.515
tmax cum 121-130	-.988*	-.869	-.173	-.558
tmax cum 131-140	-.988*	-.884	-.206	-.587
tmax cum 141-150	-.985*	-.870	-.178	-.563

	START	END	SEVERITY	LENGTH
tmax cum 1-20	-.010	-.317	-.812	-.604
tmax cum 21-40	-.421	-.704	-.931	-.888
tmax cum 41-60	-.783	-.709	-.262	-.482
tmax cum 61-80	-.934	-.723	.050	-.337
tmax cum 81-100	-.960*	-.787	-.058	-.431
tmax cum 101-120	-.984*	-.835	-.110	-.497
tmax cum 121-140	-.988	-.877	-.190	-.573
tmax cum 141 -160	-.989*	-.900	-.244	-.618
tmax cum 1-30	-.187	-.503	-.906	-.763
tmax cum 31-60	-.813	-.742	-.278	-.511
tmax cum 61-90	-.943	-.735	.053	-.350
tmax cum 91-120	-.985*	-.839	-.115	-.503
tmax cum 121-150	-.982	-.863	-.165	-.552
tmax cum 1-40	-.421	-.704	-.931	-.888
tmax cum 41-80	-.934	-.723	.050	-.337
tmax cum 81-120	-.984*	-.835	-.110	-.497
tmax cum 121-160	-.989	-.900	-.244	-.618
ymax cum 1-50	-.821	-.845	-.508	-.704
tmax cum 51-100	-.960*	-.787	-.058	-.431
tmax cum 101-150	-.984*	-.862	-.161	-.548
rain cum 1-10	.414	.722	.912	.929
rain cum 11-20	.227	.433	.524	.582
rain cum 21-30	.349	.578	.648	.723
rain cum 31-40	.296	.466	.466	.567
rain cum 41-50	.489	.647	.541	.698
rain cum 51-60	.786	.859	.498	.769
rain cum 61-70	.660	.796	.583	.791
rain cum 71-80	.871	.917	.487	.786
rain cum 81-90	.907	.954*	.517	.816
rain cum 91-100	.933	.963*	.494	.804
rain cum 101-110	.901	.901	.390	.720
rain cum 111-120	.874	.916	.478	.779
rain cum 121-130	.864	.852	.336	.668
rain cum 131-140	.878	.891	.408	.728
rain cum 141-150	.804	.892	.550	.814
rain cum 1-20	.409	.712	.892	.915
rain cum 21-40	.296	.466	.466	.567
rain cum 41-60	.786	.859	.498	.769
rain cum 61-80	.871	.917	.487	.786
rain cum 81-100	.933	.963*	.494	.804
rain cum 101-120	.874	.916	.478	.779
rain cum 121-140	.878	.891	.408	.728
rain cum 141-160	.785	.893	.590	.837

	START	END	SEVERITY	LENGTH
rain cum 161-180	.772	.893	.618	.853
rain cum 181-200	.727	.866	.634	.851
rain cum 1-30	.349	.578	.648	.723
rain cum 31-60	.786	.859	.498	.769
rain cum 61-90	.907	.954*	.517	.816
rain cum 91-120	.874	.916	.478	.779
rain cum 121-150	.804	.892	.550	.814
rain cum 151-180	.772	.893	.618	.853
rain cum 1-40	.296	.466	.466	.567
rain cum 41-80	.871	.917	.487	.786
rain cum 81-120	.874	.916	.478	.779
rain cum 121-160	.785	.893	.590	.837
rain cum 161-200	.785	.893	.590	.837
rain cum 201-240	.727	.866	.634	.851
rain cum 1-50	.489	.647	.541	.698
rain cum 51-100	.933	.963*	.494	.804
rain cum 101-150	.804	.892	.550	.814
rain cum 151-200	.727	.866	.634	.851

APPENDIX C1

Pearson correlation between meteorological variables and start day of peak value for Olea in Tirana

*correlation significant at 0.05 level **correlation significant at the 0.01 level

		Start day of peak value for Olea
rain days 1-10	Pearson Correlation	.664
rain days 10-20	Pearson Correlation	.132
rain days 20-30	Pearson Correlation	.805
rain days 30-40	Pearson Correlation	.246
rain days 40-50	Pearson Correlation	.669
rain days 50-60	Pearson Correlation	.351
rain days 60-70	Pearson Correlation	.679
rain days 70-80	Pearson Correlation	.294
rain days 80-90	Pearson Correlation	.926
rain days 90-100	Pearson Correlation	.255
rain days 100-110	Pearson Correlation	-.187
rain days 110-120	Pearson Correlation	.122
rain days 120-130	Pearson Correlation	-.309
rain days 130-140	Pearson Correlation	.984(*)
rain days 140-150	Pearson Correlation	.472
Tmax 1-10	Pearson Correlation	.278
Tmax 10-20	Pearson Correlation	-.570
Tmax20-30	Pearson Correlation	-.241
Tmax30-40	Pearson Correlation	-.425
Tmax40-50	Pearson Correlation	-.554
Tmax 50-60	Pearson Correlation	-.367
Tmax 60-70	Pearson Correlation	-.731
Tmax 70-80	Pearson Correlation	-.471
Tmax 80-90	Pearson Correlation	-.369
Tmax 90-100	Pearson Correlation	-.464
tmax 100-110	Pearson Correlation	-.953(*)
Tmax 110-120	Pearson Correlation	-.438
Tmax 120-130	Pearson Correlation	-.608
Tmax 130-140	Pearson Correlation	-.996(**)
Tmax 140-150	Pearson Correlation	.928
tmin 1-10	Pearson Correlation	.677
Tmin 10-20	Pearson Correlation	-.483
Tmin 20-30	Pearson Correlation	-.438
Tmin 30-40	Pearson Correlation	-.582
Tmin 40-50	Pearson Correlation	-.251

Tmin 50-60	Pearson Correlation	-.098
Tmin 60-70	Pearson Correlation	-.575
Tmin 70-80	Pearson Correlation	.220
Tmin 80-90	Pearson Correlation	.450
Tmin 90-100	Pearson Correlation	.156
Tmin 100-110	Pearson Correlation	-.923
Tmin 110-120	Pearson Correlation	-.922
Tmin 120-130	Pearson Correlation	-.059
Tmin 130-140	Pearson Correlation	-.683
Tmin 140-150	Pearson Correlation	.187
rain 1-20	Pearson Correlation	.505
rain 20-40	Pearson Correlation	.623
rain40-60	Pearson Correlation	.498
rain mean 61-80	Pearson Correlation	**.997(**)**
rain 80-100	Pearson Correlation	.757
rain 100-120	Pearson Correlation	-.129
rain 120-140	Pearson Correlation	.713
rain 140-160	Pearson Correlation	-.448
tmax 1-20	Pearson Correlation	-.096
tmax 20-40	Pearson Correlation	-.337
tmax 40-60	Pearson Correlation	-.473
tmax 60-80	Pearson Correlation	-.671
tmax 80-100	Pearson Correlation	-.846
tmax 100-120	Pearson Correlation	-.871
tmax 120-140	Pearson Correlation	-.869
tmax 140-160	Pearson Correlation	.419
tmin 1-20	Pearson Correlation	.386
tmin 20-40	Pearson Correlation	-.256
tmin 40-60	Pearson Correlation	.219
tmin 60-80	Pearson Correlation	-.106
tmin 80-100	Pearson Correlation	.120
tmin 100-120	Pearson Correlation	-.687
tmin 120-140	Pearson Correlation	-.451
tmin 140-160	Pearson Correlation	.628
rain 1-30	Pearson Correlation	.617
rain 30-60	Pearson Correlation	.726
rain 60-90	Pearson Correlation	.978(*)
rain 90-120	Pearson Correlation	.037
rain 120-150	Pearson Correlation	.331
tmax 1-30	Pearson Correlation	-.241
tmax 30-60	Pearson Correlation	-.532
tmax 60-90	Pearson Correlation	-.661
tmax mean 91-120	Pearson Correlation	-.980(*)
tmax 120-150	Pearson Correlation	-.737
tmin 1-30	Pearson Correlation	.547

tmin 30-60	Pearson Correlation	.000
tmin 60-90	Pearson Correlation	-.260
tmin 90-120	Pearson Correlation	-.828
tmin 120-150	Pearson Correlation	.086
rain 1-40	Pearson Correlation	.552
rain 40-80	Pearson Correlation	.825
rain 80-120	Pearson Correlation	.976(*)
rain 120-160	Pearson Correlation	-.138
tmax 1-40	Pearson Correlation	-.532
tmax 40-80	Pearson Correlation	-.661
tmax 80-120	Pearson Correlation	-.992(**)
tmax 120-160	Pearson Correlation	-.647
tmin 1-40	Pearson Correlation	.402
tmin 40-80	Pearson Correlation	-.235
tmin 80-120	Pearson Correlation	-.315
tmin 120-160	Pearson Correlation	.275
rain 1-50	Pearson Correlation	.716
rain 50-100	Pearson Correlation	.866
rain 100-150	Pearson Correlation	.104
tmax 1-50	Pearson Correlation	-.724
tmax 50-100	Pearson Correlation	-.769
tmax 100-150	Pearson Correlation	-.828
tmin 1-50	Pearson Correlation	.754
tmin 50-100	Pearson Correlation	-.257
tmin 100-150	Pearson Correlation	-.329
rain mean 10-30	Pearson Correlation	.504
rain mean 30-50	Pearson Correlation	.794
rain mean 50-70	Pearson Correlation	.992(**)
rain mean 70-90	Pearson Correlation	.661
rain mean 90-110	Pearson Correlation	-.670
rain mean 110-130	Pearson Correlation	.966(*)
rain mean 130-150	Pearson Correlation	.121
tmax mean 10-30	Pearson Correlation	-.942
tmax mean 30-50	Pearson Correlation	-.610
tmax mean 51-70	Pearson Correlation	-.630
tmax 70-90	Pearson Correlation	-.563
tmax 90-110	Pearson Correlation	-.931
tmax 110-130	Pearson Correlation	-.755
tmax 130-150	Pearson Correlation	-.196
tmin 10-30	Pearson Correlation	-.987(*)
tmin 30-50	Pearson Correlation	-.111
tmin 50-70	Pearson Correlation	-.396
tmin 70-90	Pearson Correlation	.172
tmin 90-110	Pearson Correlation	-.781
tmin 110-130	Pearson Correlation	-.288

tmin 130-150	Pearson Correlation	.578
rain mean 10-40	Pearson Correlation	.414
rain mean 40-70	Pearson Correlation	.977(*)
rain mean 70-100	Pearson Correlation	.530
rain mean 100-130	Pearson Correlation	-.155
rain mean 130-160	Pearson Correlation	-.047
tmax mean 10-40	Pearson Correlation	-.973(*)
tmax mean 40-70	Pearson Correlation	-.613
tmax mean 70-100	Pearson Correlation	-.920
tmax mean 100-130	Pearson Correlation	-.827
tmax mean 130-160	Pearson Correlation	-.150
tmin mean 10-40	Pearson Correlation	-.746
tmin mean 40-70	Pearson Correlation	-.334
tmin mean 70-100	Pearson Correlation	.057
tmin 100-130	Pearson Correlation	-.579
tmin 130-160	Pearson Correlation	.599
rain mean 10-50	Pearson Correlation	.657
rain mean 50-90	Pearson Correlation	.895
rain mean 90-130	Pearson Correlation	-.225
rain mean 130-170	Pearson Correlation	-.386
tmax mean 10-50	Pearson Correlation	-.938
tmax mean 50-90	Pearson Correlation	-.636
tmax mean 90-130	Pearson Correlation	-.846
tmax mean 130-170	Pearson Correlation	.917
tmin mean 10-50	Pearson Correlation	.796
tmin mean 51-90	Pearson Correlation	.906
tmin 90-130	Pearson Correlation	-.952(*)
tmin 130-170	Pearson Correlation	.861

Appendix D:
Pearson correlations between Urticaceae and meteorological variables with 5% method in Tirana during the four years of study
*correlation significant at 0.05 level **correlation significant at the 0.01 level

	START	END	SEVERITY	LENGTH
rain days 1-10	-.597	-.275	.528	-.016
rain days 11-20	-.936	.324	-.272	.620
rain days 21-30	-.582	-.445	.664	-.167
rain days31-40	-.898	.170	-.153	.474
rain days 41-50	.471	-.959*	.860	-.992**
rain days 51-60	.763	-.789	.647	-.954
rain days 61-70	-.861	-.196	.396	.148
rain days 71-80	.746	-.746	.559	-.911
rain days 81-90	.066	-.969*	.998**	-.852
rain days 91-100	.813	-.724	.563	-.916
rain days 101-110	-.452	.322	-.473	.441
rain days 111-120	-.212	.118	.159	.178
rain days 121-130	-.134	.264	-.485	.275
rain days 131-140	-.332	-.800	.914	-.562
rain days 141-150	-.864	.041	.202	.351
tmax 1-10	-.381	-.201	.030	-.032
tmax 11-20	-.131	.549	-.736	.517
tmax21-30	.432	.133	.028	-.045
tmax31-40	.475	.289	-.154	.073
tmax41-50	-.462	.876	-.702	.918
tmax 51-60	-.740	.800	-.650	.955
tmax 61-70	-.080	.866	-.721	.769
tmax 71-80	.546	.292	-.181	.049
tmax 81-90	.892	-.042	.024	-.362
tmax 91-100	-.553	.702	-.763	.802
tmax 101-110	.470	.751	-.777	.470
tmax 111-120	.984*	-.064	-.051	-.416
tmax 121-130	.944	.115	-.259	-.248
tmax 131-140	.396	.803	-.879	.541
tmax 141-150	-.144	-.823	.950*	-.651
tmin 1-10	-.475	-.527	.435	-.276
tmin 11-20	-.616	.776	-.790	.889
tmin 21-30	.990*	-.076	-.056	-.428
tmin 31-40	.858	.187	-.218	-.154
tmin 41-50	.917	-.180	.151	-.490
tmin 51-60	-.354	.409	-.135	.480
tmin 61-70	.028	.677	-.493	.568
tmin 71-80	.382	-.315	.483	-.409
tmin 81-90	.418	-.591	.715	-.658

	START	END	SEVERITY	LENGTH
tmin 91-100	.649	-.418	.500	-.595
tmin 101-110	.257	.853	-.814	.635
tmin 111-120	.652	.585	-.707	.262
tmin 121-130	.833	-.316	.331	-.575
tmin 131-140	.888	.244	-.337	-.117
tmin 141-150	.576	-.402	.510	-.555
rain 1-20	-.955*	.022	.169	.369
rain 21-40	-.937	-.136	.274	.227
rain41-60	.647	-.878	.753	-.988
rain 61-80	-.259	-.884	.929	-.661
rain 81-100	.382	-.967*	.948	-.966*
rain 101-120	-.889	.583	-.509	.824
rain 121-140	-.456	-.570	.483	-.320
rain 141-160	-.154	.650	-.428	.611
tmax 1-20	-.292	.130	-.328	.218
tmax 21-40	.462	.211	-.064	.011
tmax 41-60	-.611	.857	-.692	.956*
tmax 61-80	.202	.674	-.530	.502
tmax 81-100	-.133	.888	-.974*	.807
tmax 101-120	.681	.554	-.609	.224
tmax 121-140	.741	.490	-.609	.147
tmax 141-160	.298	-.691	.462	-.699
tmin 1-20	-.701	-.111	.041	.162
tmin 21-40	.872	-.140	.139	-.439
tmin 41-60	-.134	-.022	.290	.030
tmin 61-80	-.031	.256	-.005	.230
tmin 81-100	.744	-.446	.488	-.653
tmin 101-120	.093	.745	-.593	.602
tmin 121-140	.910	.023	-.062	-.314
tmin 141-160	-.566	-.248	.509	-.005
rain 1-30	-.881	-.118	.329	.222
rain 31-60	.230	-.927	.789	-.876
rain 61-90	-.113	-.930	.980*	**-.989***
rain 91-120	-.892	**.998***	-.362	.659
rain 121-150	-.830	.179	.081	.457
tmax 1-30	**-.997****	.240	-.448	.285
tmax 31-60	-.446	.852	-.666	.892
tmax 61-90	.332	.594	-.468	.386
tmax 91-120	.174	.885	-.969*	.693
tmax 121-150	.866	.300	-.412	-.061
tmin 1-30	-.491	-.397	.283	-.160
tmin 31-60	.163	.044	.182	-.022
tmin 61-90	.280	.241	-.047	.103
tmin 91-120	.226	.796	-.706	.598

	START	END	SEVERITY	LENGTH
tmin 121-150	.523	-.259	.394	-.413
rain 1-40	-.956*	-.036	.208	.320
rain 41-80	.260	-.999*	.946	-.949
rain 81-120	-.484	-.749	.812	-.463
rain 121-160	-.582	.549	-.288	.683
tmax 1-40	-.091	.484	-.686	.447
tmax 41-80	-.153	.840	-.672	.774
tmax 81-120	.427	.782	-.864	.512
tmax 121-160	.857	.158	-.371	-.179
tmin 1-40	-.046	-.506	.292	-.415
tmin 41-80	.083	.324	-.096	.246
tmin 81-120	.542	.142	-.014	-.078
tmin 121-160	.136	-.228	.452	-.245
rain 1-50	-.874	-.245	.414	.110
rain 51-100	.191	-1.000*	.964*	-.924
rain 101-150	-.952*	.432	-.244	.718
tmax 1-50	-.388	.912	-.938	.921
tmax 51-100	-.070	.893	-.763	.789
tmax 101-150	.777	.445	-.538	.096
tmin 1-50	.388	-.980*	.936	-.979*
tmin 51-100	.196	.284	-.075	.171
tmin 101-150	.317	.288	-.108	.130
rain mean 10-30	-.978*	.011	.136	.367
rain mean 31-50	-.478	-.627	.571	-.361
rain mean 51-70	-.192	-.912	.953*	-.709
rain mean 71-90	.496	-.955*	.871	-.998
rain mean 91-110	-.050	.617	-.801	.546
rain mean 111-130	-.494	-.741	.791	-.452
rain mean 131-150	-.594	.300	-.015	.474
tmax mean 10-30	.263	.774	-.917	.565
tmax mean 31-50	-.151	.795	-.611	.735
tmax 51-70	-.322	.886	-.718	.875
tmax 71-90	.729	.262	-.227	-.043
tmax 91-110	-.055	.982*	**-.987****	.860
tmax 111-130	.710	.333	-.554	.025
tmax 131-150	.891	-.217	.204	-.512
tmin 10-30	.456	.765	-.843	.487
tmin 31-50	.727	-.186	.255	-.425
tmin 51-70	-.097	.573	-.346	.525
tmin 71-90	.627	-.419	.509	-.588
tmin 91-110	-.080	.907	-.784	.805
tmin 111-130	.901	-.130	.111	-.441
tmin 131-150	-.366	-.287	.550	-.111
rain mean 10-40	-.982*	.082	.022	.430

	START	END	SEVERITY	LENGTH
rain mean 41-70	-.114	-.924	.981*	-.747
rain mean 71-100	.534	-.880	.715	-.948
rain mean 101-130	-.653	.419	-.500	.597
rain mean 131-160	-.259	.313	-.038	.362
tmax mean 10-40	.420	.792	-.823	.523
tmax mean 41-70	-.365	.889	-.721	.894
tmax mean 71-100	.470	.731	-.731	.452
tmax mean 101-130	.786	.433	-.539	.083
tmax mean 131-160	.902	-.383	.155	-.658
rain mean 10-50	-.902	-.211	.305	.150
rain mean 51-90	.136	-.996*	.976*	-.901
rain mean 91-130	-.505	.397	-.527	.525
rain mean 131-170	-.729	.752	-.720	.910
tmax mean 10-50	.110	.934	-.899	.758
tmax mean 51-90	.181	.653	-.498	.491
tmax mean 91-130	.670	.462	-.652	.149
tmax mean 131-170	.054	-.938	.998*	-.821
tmin mean 10-50	.316	-.995*	.941	-.966*
tmin 51-90	-.433	-.639	.818	-.388
tmin 91-130	.296	.770	-.910	.549
tmin 131-170	-.511	-.546	.746	-.279
tmax cum 1-10	-.304	-.158	-.035	-.024
tmax cum 11-20	-.251	.151	-.358	.221
tmax cum 21-30	-.167	.260	-.476	.283
tmax cum 31-40	.006	.471	-.688	.401
tmax cum 41-50	-.289	.909	-.961*	.883
tmax cum 51-60	-.505	.930	-.898	.980*
tmax cum 61-70	-.357	.984*	-.898	.972
tmax cum 71-80	-.152	.952	-.844	.869
tmax cum 81-90	-.046	.926	-.822	.808
tmax cum 91-100	-.150	.979*	-.896	.891
tmax cum 101-110	-.054	.969*	-.902	.848
tmax cum 111-120	.014	.955	-.896	.811
tmax cum 121-130	.131	.924	-.886	.742
tmax cum 131-140	.158	.919	-.892	.727
tmax cum 141-150	.157	.914	-.880	.724
tmax cum 1-20	-.303	.131	-.327	.223
tmax cum 21-40	-.078	.470	-.676	.430
tmax cum 41-60	-.548	.919	-.873	.986
tmax cum 61-80	-.174	.946	-.830	.872
tmax cum 81-100	-.170	.976*	-.886	.896

	START	END	SEVERITY	LENGTH
tmax cum 101-120	-.002	.955*	-.890	.817
tmax cum 121-140	.146	.921	-.889	.733
tmax cum 141 -160	.178	.916	-.901	.717
tmax cum 1-30	-.166	.268	-.483	.290
tmax cum 31-60	-.505	.937	-.896	.986*
tmax cum 61-90	-.042	.918	-.810	.800
tmax cum 91-120	.017	.951*	-.889	.806
tmax cum 121-150	.159	.911	-.873	.720
tmax cum 1-40	-.078	.470	-.676	.430
tmax cum 41-80	-.174	.946	-.830	.872
tmax cum 81-120	-.002	.955*	-.890	.817
tmax cum 121-160	.178	.916	-.901	.717
tmax cum 1-50	-.361	.915	-.946	.914
tamx cum 51-100	-.170	.976*	-.886	.896*
tamx cum 101-150	.145	.916	-.876	.730
rain cum 1-10	-.597	-.275	.528	-.016
rain cum 11-20	-.953*	.022	.172	.368
rain cum 21-30	-.880	-.122	.332	.219
rain cum 31-40	-.955	-.041	.213	.315
rain cum 41-50	-.870	-.254	.421	.101
rain cum 51-60	-.642	-.602	.711	-.279
rain cum 61-70	-.745	-.456	.608	-.116
rain cum 71-80	-.516	-.719	.807	-.425
rain cum 81-90	-.426	-.780	.866	-.511
rain cum 91-100	-.369	-.820	.893	-.565
rain cum 101-110	-.478	-.754	.810	-.469
rain cum 111-120	-.514	-.721	.807	-.428
rain cum 121-130	-.546	-.697	.747	-.395
rain cum 131-140	-.521	-.720	.787	-.425
rain cum 141-150	-.600	-.634	.753	-.322
rain cum 1-20	-.634	-.259	.511	.011
rain cum 21-40	-.955	-.041	.213	.315
rain cum 41-60	-.642	-.602	.711	-.279
rain cum 61-80	-.516	-.719	.807	-.425
rain cum 81-100	-.369	-.820	.893	-.565
rain cum 101-120	-.514	-.721	.807	-.428
rain cum 121-140	-.521	-.720	.787	-.425
rain cum 141-160	-.608	-.614	.746	-.302
rain cum 161-180	-.610	-.602	.743	-.291
rain cum 181-200	-.654	-.549	.701	-.229
rain cum 21-30	-.880	-.122	.332	.219
rain cum 31-40	-.955*	-.041	.213	.315
rain cum 41-50	-.870	-.254	.421	.101
rain cum 51-60	-.642	-.602	.711	-.279

	START	END	SEVERITY	LENGTH
rain cum 61-70	-.745	-.456	.608	-.116
rain cum 71-80	-.516	-.719	.807	-.425
rain cum 81-90	-.426	-.780	.866	-.511
rain cum 91-100	-.369	-.820	.893	-.565
rain cum 101-110	-.478	-.754	.810	-.469
rain cum 111-120	-.514	-.721	.807	-.428
rain cum 121-130	-.546	-.697	.747	-.395
rain cum 131-140	-.521	-.720	.787	-.425
rain cum 141-150	-.600	-.634	.753	-.322
rain cum 1-20	-.634	-.259	.511	.011
rain cum 21-40	-.955*	-.041	.213	.315
rain cum 41-60	-.642	-.602	.711	-.279
rain cum 61-80	-.516	-.719	.807	-.425
rain cum 81-100	-.369	-.820	.893	-.565
rain cum 101-120	-.514	-.721	.807	-.428
rain cum 121-140	-.521	-.720	.787	-.425
rain cum 141-160	-.608	-.614	.746	-.302
rain cum 161-180	-.610	-.602	.743	-.291
rain cum 181-200	-.654	-.549	.701	-.229
ain cum 1-30	-.880	-.122	.332	.219
rain cum 31-60	-.642	-.602	.711	-.279
rain cum 61-90	-.426	-.780	.866	-.511
rain cum 91-120	-.514	-.721	.807	-.428
rain cum 121-150	-.600	-.634	.753	-.322
rain cum 151-180	-.610	-.602	.743	-.291
rain cum 1-40	-.955*	-.041	.213	.315
rain cum 41-80	-.516	-.719	.807	-.425
rain cum 81-120	-.514	-.721	.807	-.428
rain cum 121-160	-.608	-.614	.746	-.302
rain cum 161-200	-.608	-.614	.746	-.302
rain cum 201-240	-.654	-.549	.701	-.229
rain cum 1-50	-.870	-.254	.421	.101
rain cum 51-100	-.369	-.820	.893	-.565
rain cum 101-150	-.600	-.634	.753	-.322
rain cum 151-200	-.654	-.549	.701	-.229

Appendix D1:
Pearson correlations between meteorological variables and start and end of peak period for Urticaceae in Tirana

*correlation significant at 0.05 level **correlation significant at the 0.01 level

		Start day of peak period for Urticaceae	End date of peak period for Urticaceae
rain days 1-10	Pearson Correlation	-.094	-.530
rain days 11-20	Pearson Correlation	**-.952(**)**	-.107
rain days 21-30	Pearson Correlation	-.052	-.695
rain days 31-40	Pearson Correlation	-.895	-.245
rain days 41-50	Pearson Correlation	.734	-.743
rain days 51-60	Pearson Correlation	.874	-.442
rain days 61-70	Pearson Correlation	-.449	-.578
rain days 71-80	Pearson Correlation	.778	-.411
rain days 81-90	Pearson Correlation	.532	-.931
rain days 91-100	Pearson Correlation	.866	-.356
rain days 101-110	Pearson Correlation	-.771	.100
rain days 111-120	Pearson Correlation	.125	.040
rain days 121-130	Pearson Correlation	-.543	.184
rain days 131-140	Pearson Correlation	.198	-.941
rain days 141-150	Pearson Correlation	-.499	-.341
Tmax 1-10	Pearson Correlation	-.499	-.389
Tmax 11-20	Pearson Correlation	-.619	.471
Tmax 21-30	Pearson Correlation	.565	.345
Tmax 31-40	Pearson Correlation	.500	.517
Tmax 41-50	Pearson Correlation	-.587	.671
Tmax 51-60	Pearson Correlation	-.846	.465
Tmax 61-70	Pearson Correlation	-.264	.835
Tmax 71-80	Pearson Correlation	.532	.551
Tmax 81-90	Pearson Correlation	.831	.370
Tmax 91-100	Pearson Correlation	-.914	.437
tmax 101-110	Pearson Correlation	.072	.962(*)
Tmax 111-120	Pearson Correlation	.795	.383
Tmax 121-130	Pearson Correlation	.639	.540
Tmax 131-140	Pearson Correlation	-.089	.976(*)
Tmax 141-150	Pearson Correlation	.404	-.875
tmin 1-10	Pearson Correlation	-.335	-.750
Tmin 11-20	Pearson Correlation	-.942	.485
Tmin 21-30	Pearson Correlation	.783	.372
Tmin 31-40	Pearson Correlation	.680	.580

Tmin 41-50	Pearson Correlation	.900	.243
Tmin 51-60	Pearson Correlation	-.142	.264
Tmin 61-70	Pearson Correlation	-.025	.700
Tmin 71-80	Pearson Correlation	.727	-.123
Tmin 81-90	Pearson Correlation	.823	-.385
Tmin 91-100	Pearson Correlation	.907	-.108
Tmin 101-110	Pearson Correlation	-.085	.970(*)
Tmin 111-120	Pearson Correlation	.186	.874
Tmin 121-130	Pearson Correlation	.942	.072
Tmin 131-140	Pearson Correlation	.598	.646
Tmin 141-150	Pearson Correlation	.866	-.125
tmin 1-30	Pearson Correlation	-.438	-.630
tmin 31-60	Pearson Correlation	.440	.136
tmin 61-90	Pearson Correlation	.417	.384
tmin 91-120	Pearson Correlation	-.020	.903
tmin 121-150	Pearson Correlation	.790	-.005
rain 81-100	Pearson Correlation	.764	.785
rain 101-120	Pearson Correlation	-.992(**)	.174
rain 121-140	Pearson Correlation	-.292	-.784
rain 141-160	Pearson Correlation	-.133	.591
tmax 1-20	Pearson Correlation	-.601	-.022
tmax 21-40	Pearson Correlation	.539	.435
tmax 41-60	Pearson Correlation	-.730	.582
tmax 61-80	Pearson Correlation	.084	.774
tmax 81-100	Pearson Correlation	-.636	.815
tmax 101-120	Pearson Correlation	.319	.862
tmax 121-140	Pearson Correlation	.315	.820
tmax 141-160	Pearson Correlation	.277	-.566
tmin 1-20	Pearson Correlation	-.703	-.440
tmin 21-40	Pearson Correlation	.879	.265
tmin 41-60	Pearson Correlation	.248	-.063
tmin 61-80	Pearson Correlation	.198	.260
tmin 81-100	Pearson Correlation	.954(*)	-.095
tmin 101-120	Pearson Correlation	-.039	.794
tmin 121-140	Pearson Correlation	.791	.441
tmin 141-160	Pearson Correlation	-.066	-.488
rain 1-30	Pearson Correlation	-.488	-.508
rain 31-60	Pearson Correlation	.441	-.825
rain 61-80	Pearson Correlation	.376	**-.999(**)**
rain 91-120	Pearson Correlation	-.973(*)	-.024
rain 121-150	Pearson Correlation	-.506	-.187
tmax 1-30	Pearson Correlation	-.594	.121
tmax 31-60	Pearson Correlation	-.545	.655
tmax 61-90	Pearson Correlation	.217	.753
tmax 91-120	Pearson Correlation	-.344	.954(*)
tmax 121-150	Pearson Correlation	.527	.691

rain 1-40	Pearson Correlation	-.648	-.465
rain 41-80	Pearson Correlation	.616	-.877
rain 81-120	Pearson Correlation	-.036	-.964(*)
rain 121-160	Pearson Correlation	-.436	.296
tmax 1-40	Pearson Correlation	-.575	.423
tmax 41-80	Pearson Correlation	-.289	.777
tmax 81-120	Pearson Correlation	-.060	.968(*)
tmax 121-160	Pearson Correlation	.445	.538
tmin 1-40	Pearson Correlation	-.108	-.540
tmin 41-80	Pearson Correlation	.243	.378
tmin 81-120	Pearson Correlation	.618	.401
tmin 121-160	Pearson Correlation	.532	-.147
rain 1-50	Pearson Correlation	-.483	-.636
rain 51-100	Pearson Correlation	.575	-.908
rain 101-150	Pearson Correlation	-.830	.003
tmax 1-50	Pearson Correlation	-.805	.725
tmax 51-100	Pearson Correlation	-.287	.865
tmax 101-150	Pearson Correlation	.405	.795
tmin 1-50	Pearson Correlation	.741	-.797
tmin 51-100	Pearson Correlation	.341	.389
tmin 101-150	Pearson Correlation	.414	.447
rain mean 10-30	Pearson Correlation	-.723	-.431
rain mean 31-50	Pearson Correlation	-.246	-.849
rain mean 51-70	Pearson Correlation	.282	-.992(**)
rain mean 71-90	Pearson Correlation	.775	-.726
rain mean 91-110	Pearson Correlation	-.570	.577
rain mean 111-130	Pearson Correlation	-.067	-.961(*)
rain mean 131-150	Pearson Correlation	-.304	.045
tmax mean 11-30	Pearson Correlation	-.291	.880
tmax mean 31-50	Pearson Correlation	-.246	.734

tmax 51-70	Pearson Correlation	-.468	.745
tmax 71-90	Pearson Correlation	.615	.601
tmax 91-110	Pearson Correlation	-.495	.951(*)
tmax 111-130	Pearson Correlation	.218	.643
tmax 131-150	Pearson Correlation	.915	.196
tmin 11-30	Pearson Correlation	-.018	.966(*)
tmin 31-50	Pearson Correlation	.859	.157
tmin 51-70	Pearson Correlation	-.038	.542
tmin 71-90	Pearson Correlation	.896	-.120
tmin 91-110	Pearson Correlation	-.311	.874
tmin 111-130	Pearson Correlation	.877	.286
tmin 131-150	Pearson Correlation	.141	-.435

rain mean 11-40	Pearson Correlation	-.816	-.365
rain mean 41-70	Pearson Correlation	.382	-.966(*)
rain mean 71-100	Pearson Correlation	.668	-.641
rain mean 101-130	Pearson Correlation	-.908	.108
rain mean 131-160	Pearson Correlation	-.010	.212
tmax mean 11-40	Pearson Correlation	.000	.979(*)
tmax mean 41-70	Pearson Correlation	-.510	.728
tmax mean 71-100	Pearson Correlation	.117	.944
tmax mean 101-130	Pearson Correlation	.401	.787
tmax mean 131-160	Pearson Correlation	.707	.020
tmin mean 11-40	Pearson Correlation	.516	.735
tmin mean 41-70	Pearson Correlation	.076	.481
tmin mean 71-100	Pearson Correlation	.876	-.002
tmin 101-130	Pearson Correlation	.355	.669
tmin 131-160	Pearson Correlation	.194	-.461
rain mean 11-50	Pearson Correlation	-.625	-.620
rain mean 51-90	Pearson Correlation	.544	-.928
rain mean 91-130	Pearson Correlation	-.826	.152
rain mean 131-170	Pearson Correlation	-.975(*)	.413
tmax mean 11-50	Pearson Correlation	-.264	.982(*)
tmax mean 51-90	Pearson Correlation	.089	.745
tmax mean 91-130	Pearson Correlation	.165	.754
tmax mean 131-170	Pearson Correlation	.549	-.903
tmin mean 11-50	Pearson Correlation	.666	-.847
tmin 51-90	Pearson Correlation	.121	-.822
tmin 91-130	Pearson Correlation	-.254	.892
tmin 110-170	Pearson Correlation	.035	-.764

Appendix E:
Results of ANOVA (SPSS output) of 2002 monthly temperature data from three sites
(Tirana, Vlore and Lezhe)

Descriptives

TEM_FEB2

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Tirana	28	16.1286	1.9590	.3702	15.3690	16.8882	11.40	19.90
Vlore	28	17.0464	1.8167	.3433	16.3420	17.7509	13.00	21.50
Lezhe	28	16.0071	2.0597	.3892	15.2085	16.8058	10.20	19.40
Total	84	16.3940	1.9799	.2160	15.9644	16.8237	10.20	21.50

Test of Homogeneity of Variances

TEM_FEB2

Levene Statistic	df1	df2	Sig.
.066	2	81	.936

ANOVA

TEM_FEB2

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	18.082	2	9.041	2.383	.099
Within Groups	307.265	81	3.793		
Total	325.347	83			

Multiple Comparisons

Dependent Variable: TEM_FEB2
Tukey HSD

(I) SITES	(J) SITES	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Tirana	Vlore	-.9179	.5205	.188	-2.1607	.3250
	Lezhe	.1214	.5205	.970	-1.1214	1.3642
Vlore	Tirana	.9179	.5205	.188	-.3250	2.1607
	Lezhe	1.0393	.5205	.120	-.2035	2.2821
Lezhe	Tirana	-.1214	.5205	.970	-1.3642	1.1214
	Vlore	-1.0393	.5205	.120	-2.2821	.2035

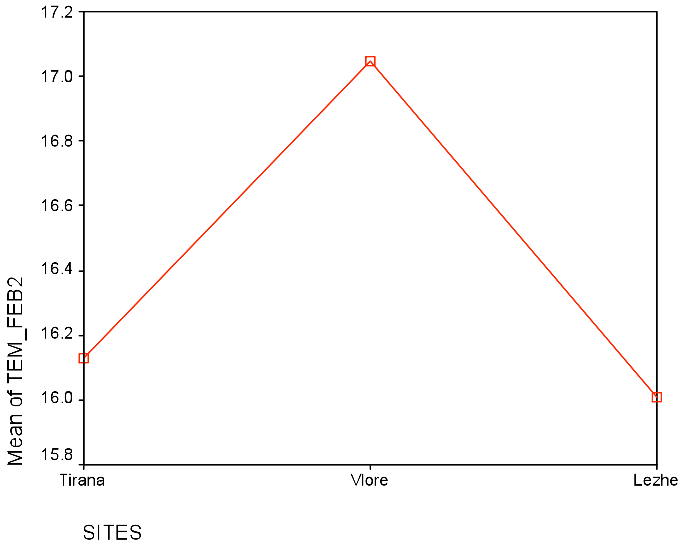
TEM_FEB2

Tukey HSD[a]

SITES	N	Subset for alpha = .05 1
Lezhe	28	16.0071
Tirana	28	16.1286
Vlore	28	17.0464
Sig.		.120

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 28.000.



Descriptives

TEMP_MR2

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	 Upper Bound	Minimum	Maximum
Tirana	31	18.3032	3.0977	.5564	17.1670	19.4395	10.80	24.70
Vlore	31	18.5258	3.9930	.7172	17.0612	19.9904	8.00	26.00
Lezhe	31	18.1387	3.2395	.5818	16.9504	19.3270	8.00	23.20
Total	93	18.3226	3.4316	.3558	17.6159	19.0293	8.00	26.00

Test of Homogeneity of Variances

TEMP_MR2

Levene Statistic	df1	df2	Sig.
1.478	2	90	.233

ANOVA

TEMP_MR2

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2.340	2	1.170	.097	.907
Within Groups	1081.023	90	12.011		
Total	1083.363	92			

Multiple Comparisons

Dependent Variable: TEMP_MR2
Tukey HSD

(I) SITES	(J) SITES	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Tirana	Vlore	-.2226	.8803	.965	-2.3204	1.8753
	Lezhe	.1645	.8803	.981	-1.9333	2.2624
Vlore	Tirana	.2226	.8803	.965	-1.8753	2.3204
	Lezhe	.3871	.8803	.899	-1.7108	2.4850
Lezhe	Tirana	-.1645	.8803	.981	-2.2624	1.9333
	Vlore	-.3871	.8803	.899	-2.4850	1.7108

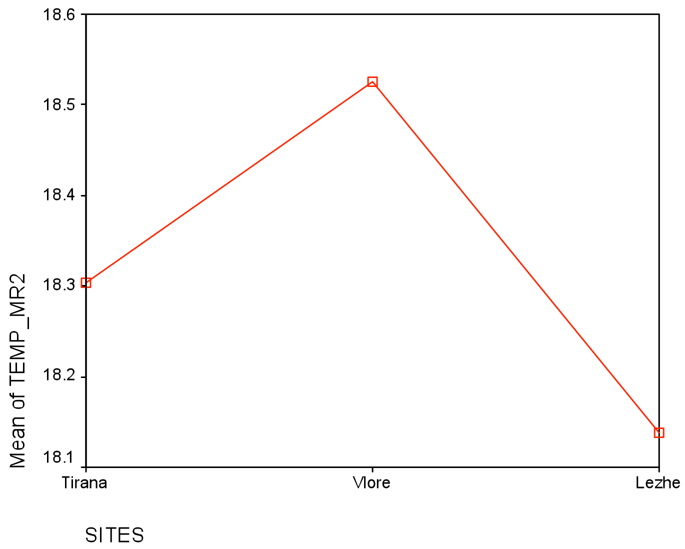
TEMP_MR2

Tukey HSD[a]

SITES	N	Subset for alpha = .05: 1
Lezhe	31	18.1387
Tirana	31	18.3032
Vlore	31	18.5258
Sig.		.899

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 31.000.



Descriptives

TEM_AP02

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
Tirana	30	19.3033	2.4598	.4491	18.3848	20.2218	14.20	24.70
Vlore	30	19.5833	2.7104	.4948	18.5713	20.5954	14.50	26.00
Lezhe	30	19.6833	2.7246	.4974	18.6659	20.7007	14.00	27.00
Total	90	19.5233	2.6097	.2751	18.9767	20.0699	14.00	27.00

Test of Homogeneity of Variances

TEM_AP02

Levene Statistic	df1	df2	Sig.
.076	2	87	.927

ANOVA

TEM_AP02

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2.328	2	1.164	.168	.846
Within Groups	603.793	87	6.940		
Total	606.121	89			

Multiple Comparisons

Dependent Variable: TEM_AP02

Tukey HSD

(I) SITES	(J) SITES	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Tirana	Vlore	-.2800	.6802	.911	-1.9019	1.3419
	Lezhe	-.3800	.6802	.842	-2.0019	1.2419
Vlore	Tirana	.2800	.6802	.911	-1.3419	1.9019
	Lezhe	-.1000	.6802	.988	-1.7219	1.5219
Lezhe	Tirana	.3800	.6802	.842	-1.2419	2.0019
	Vlore	.1000	.6802	.988	-1.5219	1.7219

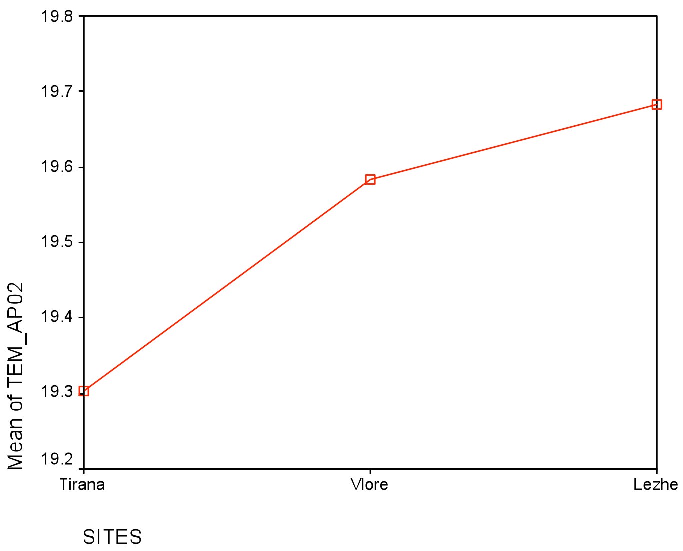
TEM_AP02

Tukey HSD[a]

SITES	N	Subset for alpha = .05
		1
Tirana	30	19.3033
Vlore	30	19.5833
Lezhe	30	19.6833
Sig.		.842

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 30.000.



Descriptives

TEM_MAY2

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
Tirana	31	23.8452	2.4691	.4435	22.9395	24.7508	18.70	27.20
Vlore	31	23.7806	1.7856	.3207	23.1257	24.4356	21.00	27.00
Lezhe	31	24.4516	2.1471	.3856	23.6641	25.2392	19.70	30.00
Total	93	24.0258	2.1502	.2230	23.5830	24.4686	18.70	30.00

Test of Homogeneity of Variances

TEM_MAY2

Levene Statistic	df1	df2	Sig.
1.272	2	90	.285

ANOVA

TEM_MAY2

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	8.495	2	4.248	.917	.403
Within Groups	416.843	90	4.632		
Total	425.338	92			

Multiple Comparisons

Dependent Variable: TEM_MAY2
Tukey HSD

(I) SITES	(J) SITES	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Tirana	Vlore	6.452E-02	.5466	.992	-1.2382	1.3672
	Lezhe	-.6065	.5466	.511	-1.9092	.6962
Vlore	Tirana	-6.4516E-02	.5466	.992	-1.3672	1.2382
	Lezhe	-.6710	.5466	.440	-1.9737	.6317
Lezhe	Tirana	.6065	.5466	.511	-.6962	1.9092
	Vlore	.6710	.5466	.440	-.6317	1.9737

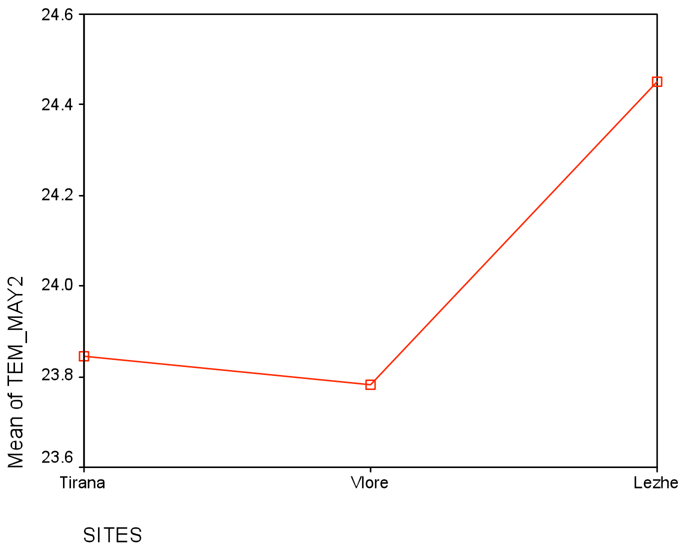
TEM_MAY2

Tukey HSD[a]

SITES	N	Subset for alpha = .05 1
Vlore	31	23.7806
Tirana	31	23.8452
Lezhe	31	24.4516
Sig.		.440

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 31.000.


24.6
24.4
24.2
24.0
23.8
23.6
Mean of TEM_MAY2
Tirana
Vlore
Lezhe
SITES

Appendix F:
Results of ANOVA (SPSS output) of 2003 monthly temperature data from three sites (Tirana, Vlore and Lezhe)

Descriptives

TEM_JAN3

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Tirana	31	14.0000	2.1630	.3885	13.2066	14.7934	8.20	17.40
Vlore	31	15.5677	3.0935	.5556	14.4330	16.7024	9.80	22.70
Lezhe	31	12.1258	3.0548	.5487	11.0053	13.2463	3.00	17.60
Total	93	13.8978	3.1129	.3228	13.2567	14.5390	3.00	22.70

Test of Homogeneity of Variances

TEM_JAN3

Levene Statistic	df1	df2	Sig.
.961	2	90	.386

ANOVA

TEM_JAN3

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	184.112	2	92.056	11.712	.000
Within Groups	707.407	90	7.860		
Total	891.520	92			

Multiple Comparisons

Dependent Variable: TEM_JAN3
Tukey HSD

(I) SITES	(J) SITES	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Tirana	Vlore	-1.5677	.7121	.076	-3.2648	.1293
	Lezhe	1.8742*	.7121	.027	.1772	3.5712
Vlore	Tirana	1.5677	.7121	.076	-.1293	3.2648
	Lezhe	3.4419*	.7121	.000	1.7449	5.1390
Lezhe	Tirana	-1.8742*	.7121	.027	-3.5712	-.1772
	Vlore	-3.4419*	.7121	.000	-5.1390	-1.7449

*. The mean difference is significant at the .05 level.

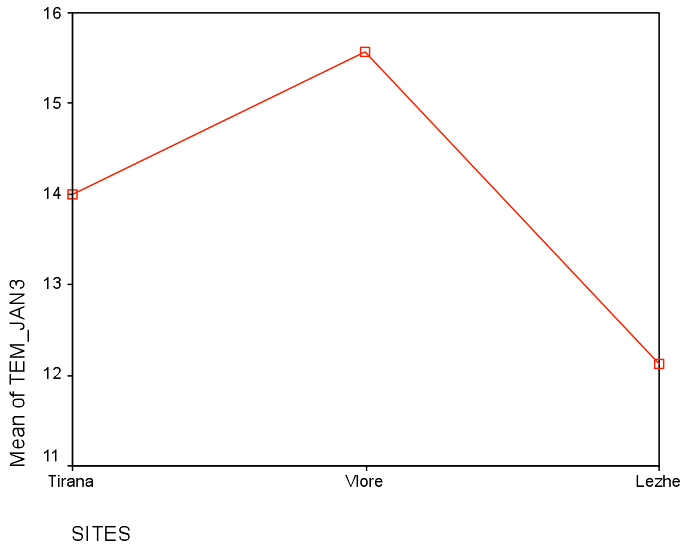
TEM_JAN3

Tukey HSD[a]

SITES	N	Subset for alpha = .05 1	2
Lezhe	31	12.1258	
Tirana	31		14.0000
Vlore	31		15.5677
Sig.		1.000	.076

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 31.000.



Descriptives

TEM_FEB3

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	Upper Bound	Minimum	Maximum
Tirana	28	10.0357	2.4263	.4585	9.0949	10.9765	5.00	15.40
Vlore	28	11.1214	2.1240	.4014	10.2978	11.9450	6.50	15.20
Lezhe	28	8.7964	2.9770	.5626	7.6421	9.9508	1.10	14.00
Total	84	9.9845	2.6793	.2923	9.4031	10.5660	1.10	15.40

Test of Homogeneity of Variances

TEM_FEB3

Levene Statistic	df1	df2	Sig.
1.035	2	81	.360

ANOVA

TEM_FEB3

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	75.789	2	37.894	5.902	.004
Within Groups	520.041	81	6.420		
Total	595.830	83			

Multiple Comparisons

Dependent Variable: TEM_FEB3
Tukey HSD

(I) SITES	(J) SITES	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Tirana	Vlore	-1.0857	.6772	.250	-2.7025	.5311
	Lezhe	1.2393	.6772	.166	-.3775	2.8561
Vlore	Tirana	1.0857	.6772	.250	-.5311	2.7025
	Lezhe	2.3250*	.6772	.003	.7082	3.9418
Lezhe	Tirana	-1.2393	.6772	.166	-2.8561	.3775
	Vlore	-2.3250*	.6772	.003	-3.9418	-.7082

*. The mean difference is significant at the .05 level.

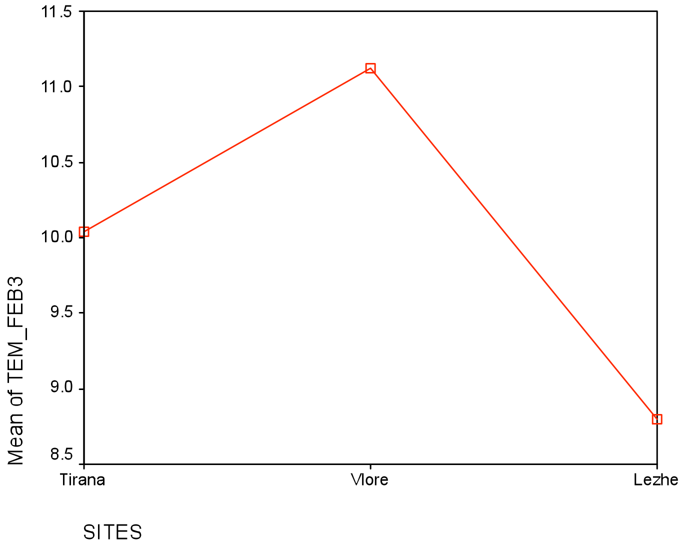
TEM_FEB3

Tukey HSD[a]

SITES	N	Subset for alpha = .05	
		1	2
Lezhe	28	8.7964	
Tirana	28	10.0357	10.0357
Vlore	28		11.1214
Sig.		.166	.250

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 28.000.



Descriptives

TEM_MR3

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Tirana	31	16.0419	2.3303	.4185	15.1872	16.8967	10.50	19.80
Vlore	31	16.0097	2.2182	.3984	15.1960	16.8233	11.50	19.70
Lezhe	31	15.2548	2.6985	.4847	14.2650	16.2447	10.00	19.30
Total	93	15.7688	2.4256	.2515	15.2693	16.2684	10.00	19.80

Test of Homogeneity of Variances

TEM_MR3

Levene Statistic	df1	df2	Sig.
1.192	2	90	.308

ANOVA

TEM_MR3

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	12.300	2	6.150	1.046	.355
Within Groups	528.979	90	5.878		
Total	541.280	92			

Descriptives

TEM_MAY3

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
Tirana	31	27.9194	3.0046	.5396	26.8173	29.0215	19.60	32.20
Vlore	31	26.0419	2.5154	.4518	25.1193	26.9646	20.00	30.20
Lezhe	31	27.3452	3.2823	.5895	26.1412	28.5491	17.80	32.50
Total	93	27.1022	3.0239	.3136	26.4794	27.7249	17.80	32.50

Multiple Comparisons

Dependent Variable: TEM_MR3

Tukey HSD

(I) SITES	(J) SITES	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Tirana	Vlore	3.226E-02	.6158	.998	-1.4352	1.4998
	Lezhe	.7871	.6158	.411	-.6804	2.2546
Vlore	Tirana	-3.2258E-02	.6158	.998	-1.4998	1.4352
	Lezhe	.7548	.6158	.441	-.7127	2.2223
Lezhe	Tirana	-.7871	.6158	.411	-2.2546	.6804
	Vlore	-.7548	.6158	.441	-2.2223	.7127

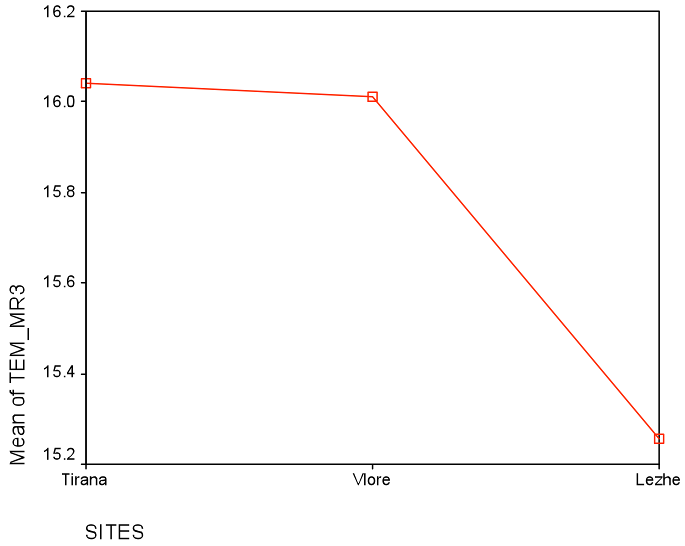
TEM_MR3

Tukey HSD[a]

SITES	N	Subset for alpha = .05 1
Lezhe	31	15.2548
Vlore	31	16.0097
Tirana	31	16.0419
Sig.		.411

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 31.000.



Test of Homogeneity of Variances

TEM_MAY3

Levene Statistic	df1	df2	Sig.
.448	2	90	.640

ANOVA

TEM_MAY3

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	57.379	2	28.689	3.294	.042
Within Groups	783.841	90	8.709		
Total	841.220	92			

Multiple Comparisons

Dependent Variable: TEM_MAY3
Tukey HSD

(I) SITES	(J) SITES	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Tirana	Vlore	1.8774*	.7496	.037	9.105E-02	3.6638
	Lezhe	.5742	.7496	.725	-1.2122	2.3606
Vlore	Tirana	-1.8774*	.7496	.037	-3.6638	-9.1047E-02
	Lezhe	-1.3032	.7496	.197	-3.0896	.4831
Lezhe	Tirana	-.5742	.7496	.725	-2.3606	1.2122
	Vlore	1.3032	.7496	.197	-.4831	3.0896

*. The mean difference is significant at the .05 level.

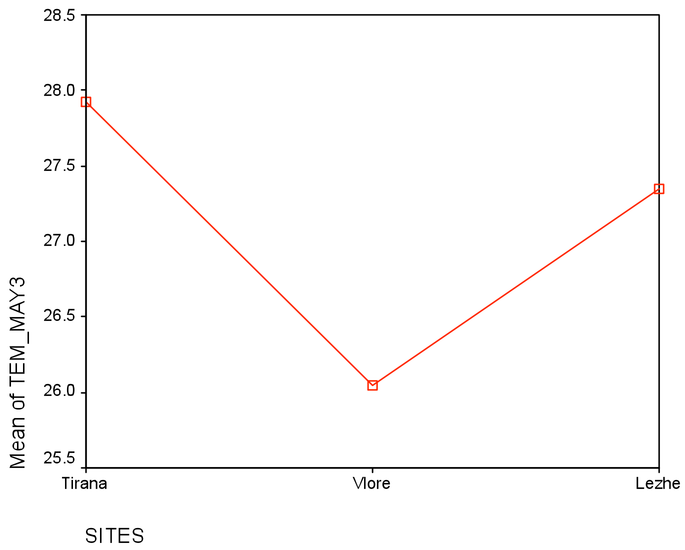
TEM_MAY3

Tukey HSD[a]

SITES	N	Subset for alpha = .05	
		1	2
Vlore	31	26.0419	
Lezhe	31	27.3452	27.3452
Tirana	31		27.9194
Sig.		.197	.725

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 31.000.



Descriptives

TEM_APR3

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Tirana	30	18.9533	4.1947	.7658	17.3870	20.5197	7.80	25.50
Vlore	30	18.5800	3.5174	.6422	17.2666	19.8934	9.50	24.70
Lezhe	30	18.7433	4.2885	.7830	17.1420	20.3447	10.00	26.00
Total	90	18.7589	3.9725	.4187	17.9269	19.5909	7.80	26.00

Test of Homogeneity of Variances

TEM_APR3

Levene Statistic	df1	df2	Sig.
.798	2	87	.453

ANOVA

TEM_APR3

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2.102	2	1.051	.065	.937
Within Groups	1402.416	87	16.120		
Total	1404.518	89			

Multiple Comparisons

Dependent Variable: TEM_APR3
Tukey HSD

(I) SITES	(J) SITES	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Tirana	Vlore	.3733	1.0367	.931	-2.0986	2.8452
	Lezhe	.2100	1.0367	.978	-2.2619	2.6819
Vlore	Tirana	-.3733	1.0367	.931	-2.8452	2.0986
	Lezhe	-.1633	1.0367	.986	-2.6352	2.3086
Lezhe	Tirana	-.2100	1.0367	.978	-2.6819	2.2619
	Vlore	.1633	1.0367	.986	-2.3086	2.6352

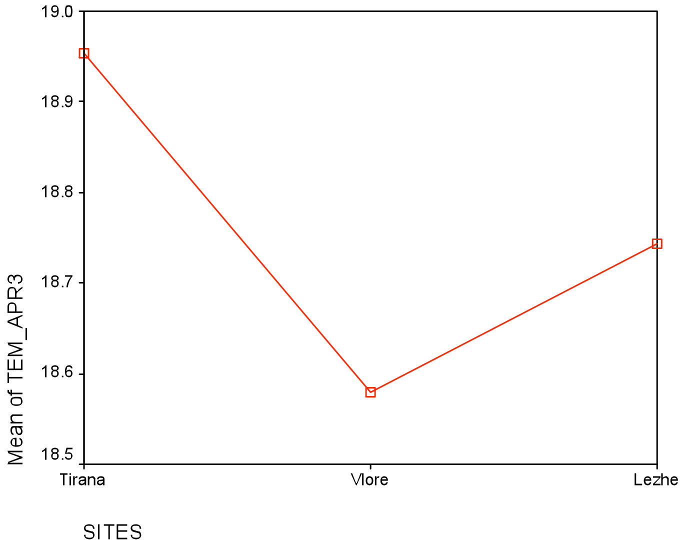
TEM_APR3

Tukey HSD[a]

SITES	N	Subset for alpha = .05
		1
Vlore	30	18.5800
Lezhe	30	18.7433
Tirana	30	18.9533
Sig.		.931

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 30.000.


19.0
18.9
18.8
18.7
18.6
18.5
Mean of TEM_APR3
Tirana
Vlore
Lezhe
SITES

Appendix G:
Results of Kruskal-Wallace test (SPSS output) of monthly temperature data from three sites (Tirana, Vlore and Lezhe)

Jan 2003

Ranks

	SITES	N	Mean Rank
TEM_JAN	Tirana	31	48.45
	Vlore	31	61.26
	Lezhe	31	31.29
	Total	93	

Test Statistics[a,b]

	TEM_JAN
Chi-Square	19.265
df	2
Asymp. Sig.	.000

a. Kruskal Wallis Test

b. Grouping Variable: SITES

Feb 2003

Ranks

	SITES	N	Mean Rank
TEM_FEB	Tirana	28	41.43
	Vlore	28	53.59
	Lezhe	28	32.48
	Total	84	

Test Statistics[a,b]

	TEM_FEB
Chi-Square	10.583
df	2
Asymp. Sig.	.005

a. Kruskal Wallis Test

b. Grouping Variable: SITES

March 2003

Ranks

	SITES	N	Mean Rank
TEM_MARC	Tirana	31	46.29
	Vlore	31	45.66
	Lezhe	22	32.70
	Total	84	

Test Statistics[a,b]

	TEM_MARC
Chi-Square	4.823
df	2
Asymp. Sig.	.090

a. Kruskal Wallis Test

b. Grouping Variable: SITES

April 2003

Ranks

	SITES	N	Mean Rank
TEMP_APR	Tirana	30	48.37
	Vlore	30	43.33
	Lezhe	30	44.80
	Total	90	

Test Statistics[a,b]

	TEMP_APR
Chi-Square	.590
df	2
Asymp. Sig.	.745

a. Kruskal Wallis Test

b. Grouping Variable: SITES

May 2003

Ranks

	SITES	N	Mean Rank
TEM_MAY	Tirana	31	55.63
	Vlore	31	35.94
	Lezhe	31	49.44
	Total	93	

Test Statistics[a,b]

	TEM_MAY
Chi-Square	8.640
df	2
Asymp. Sig.	.013

a. Kruskal Wallis Test

b. Grouping Variable: SITES

APPENDIX H: MODEL SUMMARY TABLE AND COEFFICIENTS TABLE PRODUCED BY SPSS FOLLOWING SIMPLE LINEAR REGRESSION ANALYSIS FOR TIRANA DATA

APPENDIX H1: SIMPLE LINEAR MODEL PREDICTING THE START OF GRASS POLLEN SEASON

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.992[a]	.984	.976	1.27635

a. Predictors: (Constant), Tmax 61-70

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	152.632	2.687		56.807	.000
	Tmax 61-70	-1.956	.177	-.992	-11.066	.008

a. Dependent Variable: Start date of grass pollen season

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.990[a]	.980	.970	.71665

a. Predictors: (Constant), rain days 11-20

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	195.972	.525		373.138	.000
	rain days 11-20	.779	.079	.990	9.839	.010

a. Dependent Variable: End date of grass pollen season

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.990[a]	.980	.970	87.69747

a. Predictors: (Constant), rain 121-160

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	3529.228	181.984		19.393	.003
	rain 121-160	-464.073	46.480	-.990	-9.984	.010

a. Dependent Variable: Severity of grass pollen season

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.999[a]	.997	.996	.60785

a. Predictors: (Constant), Tmax 41-50

b. Dependent Variable: Length of the grass pollen season

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	18.832	2.222		8.476	.014		
	Tmax 41-50	3.806	.147	.999	25.974	.001	1.000	1.000

a. Dependent Variable: Length of the grass pollen season

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.989[a]	.978	.967	.34922

a. Predictors: (Constant), tmin 1-50

b. Dependent Variable: Start of peak period

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	116.268	2.161		53.795	.000
	tmin 1-50	5.122	.545	.989	9.391	.011

a. Dependent Variable: Start of peak period

APPENDIX H6: SIMPLE LINEAR MODEL PREDICTING THE DAY OF PEAK COUNT FOR GRASS POLLEN SEASON

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.998[a]	.997	.995	.35264

a. Predictors: (Constant), rain 60-80

b. Dependent Variable: Peak value

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	137.326	.326		421.412	.000		
	rain 60-80	1.348	.055	.998	24.353	.002	1.000	1.000

a. Dependent Variable: Peak value

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.919[a]	.845	.767	2.53506

a. Predictors: (Constant), tmin 1-10

b. Dependent Variable: End of peak period

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	173.830	1.771		98.145	.000		
	tmin 1-10	-1.189	.360	-.919	-3.298	.081	1.000	1.000

a. Dependent Variable: End of peak period

APPENDIX J : MODEL SUMMARY TABLES AND COEFFICIENTS TABLES PRODUCED BY SPSS FOLLOWING MULTIPLE REGRESSION ANALYSIS FOR GRASS, TIRANA DATA

APPENDIX J1: MULTIPLE REGRESSION MODEL- PRE-PEAK PERIOD

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	,708[a]	,502	,490	2,14065

a. Predictors: (Constant), Temperature maximum, two days running mean

b. Dependent Variable: normalised Grass pre-peak 5% method

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	,379	1,936		,196	,845		
	two days running mean	,095	,011	,685	8,702	,000	,923	1,083
	Temperature maximum	,078	,087	,071	,897	,372	,923	1,083

a. Dependent Variable: normalised Grass pre-peak 5% method

APPENDIX J2: CORRELATION ANALYSIS BETWEEN NORMALISED GRASS POLLEN COUNTS AND METEREOLOGICAL VARIABLES DURING THE PRE-PEAK PERIOD IN TIRANA

Correlations

		normalised daily Grass pollen count (pre-peak)
five days running mean normalised grass pollen count	Pearson Correlation	.695**
	Sig. (2-tailed)	.000
	N	90
four days running mean normalised grass pollen count	Pearson Correlation	.700**
	Sig. (2-tailed)	.000
	N	90
three days running mean normalised grass pollen count	Pearson Correlation	.681**
	Sig. (2-tailed)	.000
	N	90
two days running mean normalised grass pollen count (pre-peak)	Pearson Correlation	.705**
	Sig. (2-tailed)	.000
	N	90
Temperature maximum	Pearson Correlation	.261*
	Sig. (2-tailed)	.013
	N	90
Temperature minimum	Pearson Correlation	.183
	Sig. (2-tailed)	.085
	N	90
Rainfall-prepeak	Pearson Correlation	-.079
	Sig. (2-tailed)	.460
	N	90

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

APPENDIX J3: MULTIPLE REGRESSION MODEL PRE-PEAK PERIOD FOR GRASS

			Case Number	Value
Mahalanobis Distance	Highest	1	35	14,14808
		2	40	10,58283
		3	63	9,86901
		4	39	8,89486
		5	41	8,89169
	Lowest	1	77	,01330
		2	84	,02865
		3	87	,07410
		4	21	,12685
		5	33	,16135

APPENDIX J4: MULTIPLE REGRESSION MODEL FOR GRASS IN THE PEAK PERIOD

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.634[a]	.403	.391	1.98246

a. Predictors: (Constant), Temperature minimum, five days running mean

b. Dependent Variable: normalised daily Grass pollen count (peak period)

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	.859	1.595		.539	.591		
	five days running mean	.068	.009	.675	7.675	.000	.772	1.295
	Temperature minimum	.091	.083	.097	1.103	.273	.772	1.295

a. Dependent Variable: normalised daily Grass pollen count (peak period)

APPENDIX J5: CORRELATION ANALYSIS BETWEEN NORMALISED GRASS POLLEN COUNTS AND METEREOLOGICAL VARIABLES DURING THE PEAK PERIOD IN TIRANA

Correlations

		normalised Grass peak 5%
five days running mean	Pearson Correlation	.629**
	Sig. (2-tailed)	.000
	N	103
four days running mean	Pearson Correlation	.591**
	Sig. (2-tailed)	.000
	N	103
three days running mean	Pearson Correlation	.542**
	Sig. (2-tailed)	.000
	N	103
two days running mean	Pearson Correlation	.545**
	Sig. (2-tailed)	.000
	N	103
Temperature maximum	Pearson Correlation	-.009
	Sig. (2-tailed)	.931
	N	103
Temperature minimum	Pearson Correlation	-.225*
	Sig. (2-tailed)	.022
	N	103
Rainfall	Pearson Correlation	-.157
	Sig. (2-tailed)	.114
	N	103

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

APPENDIX J6: MULTIPLE REGRESSION MODEL PEAK PERIOD FOR GRASS POLLEN

Extreme Values

			Case Number	Value
Mahalanobis Distance	Highest	1	45	14,31863
		2	46	12,74349
		3	76	7,72686
		4	75	5,93418
		5	50	5,63369
	Lowest	1	82	,00180
		2	6	,00844
		3	12	,02419
		4	38	,02609
		5	39	,02697

APPENDIX J7: MULTIPLE REGRESSION MODEL- POST- PEAK PERIOD FOR GRASS POLLEN

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.459[a]	.210	.197	1.13174

a. Predictors: (Constant), Temperature minimum, two days running mean normalised grass pollen count

b. Dependent Variable: normalised daily Grass pollen count (post-peak period)

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	3.064	.645		4.753	.000
	two days running mean normalised grass pollen count	.067	.014	.405	4.768	.000
	Temperature minimum	-.053	.032	-.144	-1.690	.094

a. Dependent Variable: normalised daily Grass pollen count (post-peak period)

APPENDIX J8: CORRELATION ANALYSIS BETWEEN NORMALISED GRASS POLLEN COUNTS AND METEREOLOGICAL VARIABLES DURING THE POST-PEAK PERIOD IN TIRANA

Correlations

		normalised daily Grass pollen count (post-peak period)
five days running mean	Pearson Correlation	.427**
	Sig. (2-tailed)	.000
	N	118
four days running mean	Pearson Correlation	.391**
	Sig. (2-tailed)	.000
	N	118
three days running mean	Pearson Correlation	.391**
	Sig. (2-tailed)	.000
	N	118
two days running mean normalised grass pollen count	Pearson Correlation	.437**
	Sig. (2-tailed)	.000
	N	118
Temperature maximum	Pearson Correlation	-.141
	Sig. (2-tailed)	.129
	N	118
Temperature minimum	Pearson Correlation	-.233*
	Sig. (2-tailed)	.011
	N	118
Rainfall	Pearson Correlation	-.111
	Sig. (2-tailed)	.233
	N	118

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

APPENDIX J9: MULTIPLE REGRESSION MODEL POST- PEAK PERIOD FOR GRASS

Extreme Values

			Case Number	Value
Mahalanobis Distance	Highest	1	29	13,84382
		2	30	10,88610
		3	100	8,73143
		4	63	8,43066
		5	31	8,09118
	Lowest	1	74	,00024
		2	5	,18760
		3	52	,20335
		4	51	,23559
		5	3	,24794

APPENDIX K : MODEL SUMMARY TABLES AND COEFFICIENTS TABLES PRODUCED BY SPSS FOLLOWING MULTIPLE REGRESSION ANALYSIS FOR GRASS ON NON-RAINY DAYS, TIRANA DATA

APPENDIX K1: MULTIPLE REGRESSION MODEL- PRE-PEAK PERIOD ON NON-RAINY DAYS

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.774[a]	.599	.586	2.06218

a. Predictors: (Constant), Temperature minimum, two days running mean

b. Dependent Variable: normalised daily Grass pollen count on non-rainy days (pre-peak period)

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	.097	1.549		.063	.950		
	two days running mean	.095	.011	.739	8.703	.000	.927	1.078
	Temperature minimum	.151	.120	.107	1.259	.213	.927	1.078

a. Dependent Variable: normalised daily Grass pollen count on non-rainy days (pre-peak period)

APPENDIX K2: CORRELATION ANALYSIS BETWEEN NORMALISED GRASS POLLEN COUNTS AND METEREOLOGICAL VARIABLES DURING THE PRE-PEAK PERIOD IN TIRANA ON NON-RAINY DAYS

Correlations

		normalised daily Grass pollen count on non-rainy days (pre-peak period)
five days running mean normalised grass pollen count on non-rainy days (pre-peak period)	Pearson Correlation	.765**
	Sig. (2-tailed)	.000
	N	63
four days running mean	Pearson Correlation	.766**
	Sig. (2-tailed)	.000
	N	63
three days running mean	Pearson Correlation	.742**
	Sig. (2-tailed)	.000
	N	63
two days running mean	Pearson Correlation	.767**
	Sig. (2-tailed)	.000
	N	63
Temperature maximum	Pearson Correlation	.235
	Sig. (2-tailed)	.063
	N	63
Temperature minimum	Pearson Correlation	.306*
	Sig. (2-tailed)	.015
	N	63

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

APPENDIX K3: MULTIPLE REGRESSION MODEL PRE-PEAK PERIOD FOR GRASS ON NON-RAINY DAYS

Extreme Values

			Case Number	Value
Mahalanobis Distance	Highest	1	25	10.23243
		2	28	7.87783
		3	26	7.85052
		4	27	7.04071
		5	18	5.31522
	Lowest	1	11	.00540
		2	55	.12149
		3	61	.17345
		4	10	.27776
		5	54	.31397

APPENDIX K4: MULTIPLE REGRESSION MODEL FOR GRASS IN THE PEAK PERIOD ON NON-RAINY DAYS

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	,615[a]	,378	,363	2,21987

a. Predictors: (Constant), Temperature minimum, five days running mean

b. Dependent Variable: normalised Grass peak dry days

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	4,731	1,992		2,374	,020		
	five days running mean	,062	,011	,563	5,693	,000	,767	1,304
	Temperature minimum	-,101	,104	-,096	-,974	,333	,767	1,304

a. Dependent Variable: normalised Grass peak dry days

Correlations

		normalised daily Grass pollen count on non-rainy days (peak period)
five days running mean	Pearson Correlation	.609**
	Sig. (2-tailed)	.000
	N	86
four days running mean	Pearson Correlation	.582**
	Sig. (2-tailed)	.000
	N	86
three days running mean	Pearson Correlation	.554**
	Sig. (2-tailed)	.000
	N	86
two days running mean normalised grass pollen count on non-rainy days	Pearson Correlation	.572**
	Sig. (2-tailed)	.000
	N	86
Temperature maximum	Pearson Correlation	-.207
	Sig. (2-tailed)	.056
	N	86
Temperature minimum	Pearson Correlation	-.368**
	Sig. (2-tailed)	.000
	N	86

**. Correlation is significant at the 0.01 level (2-tailed).

APPENDIX K6: MULTIPLE REGRESSION MODEL PEAK PERIOD FOR GRASS POLLEN ON NON-RAINY DAYS

Extreme Values

			Case Number	Value
Mahalanobis Distance	Highest	1	70	7,06051
		2	71	6,49082
		3	46	5,74929
		4	44	5,55948
		5	47	5,15727
	Lowest	1	6	,03534
		2	55	,15542
		3	38	,16464
		4	13	,17014
		5	12	,21135

APPENDIX K7: SIMPLE REGRESSION MODEL- POST- PEAK PERIOD FOR GRASS POLLEN ON NON-RAINY DAYS

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.568[a]	.323	.314	1.11528

a. Predictors: (Constant), two days running mean normalised grass pollen count

b. Dependent Variable: normalised daily Grass pollen count on non-rainy days (post-peak period)

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.917	.210		9.142	.000
	two days running mean normalised grass pollen count	.082	.014	.568	6.015	.000

a. Dependent Variable: normalised daily Grass pollen count on non-rainy days (post-peak period)

APPENDIX K8: CORRELATION ANALYSIS BETWEEN NORMALISED GRASS POLLEN COUNTS AND METEREOLOGICAL VARIABLES DURING THE POST-PEAK PERIOD IN TIRANA ON NON-RAINY DAYS

Correlations

		normalised daily Grass pollen count on non-rainy days (post-peak period)
five days running mean normalised grass pollen count	Pearson Correlation	.550**
	Sig. (2-tailed)	.000
	N	78
four days running mean	Pearson Correlation	.529**
	Sig. (2-tailed)	.000
	N	78
three days running mean	Pearson Correlation	.532**
	Sig. (2-tailed)	.000
	N	78
two days running mean normalised grass pollen count	Pearson Correlation	.568**
	Sig. (2-tailed)	.000
	N	78
Temperature maximum	Pearson Correlation	.033
	Sig. (2-tailed)	.777
	N	78
Temperature minimum	Pearson Correlation	-.209
	Sig. (2-tailed)	.067
	N	78

**. Correlation is significant at the 0.01 level (2-tailed).

APPENDIX K9: MULTIPLE REGRESSION MODEL POST- PEAK PERIOD FOR GRASS ON NON-RAINY DAYS

Extreme Values

			Case Number	Value
Mahalanobis Distance	Highest	1	28	19,95285
		2	29	16,83835
		3	30	9,07961
		4	31	4,82055
		5	71	3,35685
	Lowest	1	75	,00023
		2	61	,00023
		3	40	,00023
		4	39	,00023
		5	38	,00023[a]

a. Only a partial list of cases with the value ,00023 are shown in the table of lower extremes.

APPENDIX L: MODEL SUMMARY TABLE AND COEFFICIENTS TABLE PRODUCED BY SPSS FOLLOWING SIMPLE LINEAR REGRESSION ANALYSIS FOR TIRANA DATA FOR OLEA

APPENDIX L1: SIMPLE LINEAR MODEL PREDICTING THE START OF OLEA POLLEN SEASON

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.999[a]	.997	.996	.41453

a. Predictors: (Constant), tmax mean 51-70

b. Dependent Variable: Start date of Olea pollen season

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	166.376	1.109		150.060	.000		
	tmax mean 51-70	-1.960	.070	-.999	-27.889	.001	1.000	1.000

a. Dependent Variable: Start date of Olea pollen season

APPENDIX L2: SIMPLE LINEAR MODEL PREDICTING THE END OF OLEA POLLEN SEASON

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.998[a]	.997	.995	.92922

a. Predictors: (Constant), tmax mean 91-120

b. Dependent Variable: End date of Olea pollen season

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	366.201	8.004		45.753	.000		
	tmax mean 91-120	-10.823	.440	-.998	-24.617	.002	1.000	1.000

a. Dependent Variable: End date of Olea pollen season

APPENDIX L3: SIMPLE LINEAR MODEL PREDICTING THE SEVERITY OF OLEA POLLEN SEASON

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.997[a]	.993	.990	64.93689

a. Predictors: (Constant), tmin mean 51-90

b. Dependent Variable: Severity of Olea pollen season

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	389.569	54.886		7.098	.019		
	tmin mean 51-90	220.125	12.827	.997	17.161	.003	1.000	1.000

a. Dependent Variable: Severity of Olea pollen season

APPENDIX L4: SIMPLE LINEAR MODEL PREDICTING THE LENGTH OF OLEA POLLEN SEASON

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.977[a]	.955	.933	2.75605

a. Predictors: (Constant), tmin mean 51-90

b. Dependent Variable: Length of the Olea pollen season

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	21.237	2.329		9.117	.012		
	tmin mean 51-90	3.554	.544	.977	6.529	.023	1.000	1.000

a. Dependent Variable: Length of the Olea pollen season

APPENDIX L5: SIMPLE LINEAR MODEL PREDICTING THE DAY OF PEAK COUNT FOR OLEA POLLEN SEASON

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.997[a]	.994	.991	.58280

a. Predictors: (Constant), rain mean 61-80

b. Dependent Variable: Start of peak day for Olea

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	137.654	.539		255.594	.000		
	rain mean 61-80	1.686	.091	.997	18.426	.003	1.000	1.000

a. Dependent Variable: Start of peak day for Olea

APPENDIX M : MODEL SUMMARY TABLES AND COEFFICIENTS TABLES PRODUCED BY SPSS FOLLOWING MULTIPLE REGRESSION ANALYSIS FOR OLEA, TIRANA DATA

APPENDIX M1: MULTIPLE REGRESSION MODEL- PRE-PEAK PERIOD

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.591[a]	.349	.320	3.52040

a. Predictors: (Constant), Temperature maximum, five-days running mean Olea pollen count

b. Dependent Variable: normalised Olea pollen count in pre-peak period

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	-5.519	4.966		-1.111	.272		
	five- days running mean Olea pollen count	.079	.023	.456	3.385	.001	.796	1.256
	Temperature maximum	.366	.222	.222	1.650	.106	.796	1.256

a. Dependent Variable: normalised Olea pollen count in pre-peak period

APPENDIX M2: CORRELATION ANALYSIS BETWEEN NORMALISED OLEA POLLEN COUNTS AND METEREOLOGICAL VARIABLES DURING THE PRE-PEAK PERIOD IN TIRANA

Correlations

		normalised Olea pollen count in pre-peak period
Temperature maximum	Pearson Correlation	.428**
	Sig. (2-tailed)	.002
	N	48
Temperature minimum	Pearson Correlation	.295*
	Sig. (2-tailed)	.042
	N	48
rainfall	Pearson Correlation	-.150
	Sig. (2-tailed)	.310
	N	48
five- days running mean Olea pollen count	Pearson Correlation	.557**
	Sig. (2-tailed)	.000
	N	48
four- days running mean Olea pollen count	Pearson Correlation	.383**
	Sig. (2-tailed)	.007
	N	48
three- days running mean Olea pollen count	Pearson Correlation	.243
	Sig. (2-tailed)	.096
	N	48
two- days running mean Olea pollen count	Pearson Correlation	.300*
	Sig. (2-tailed)	.038
	N	48

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

APPENDIX M3: MULTIPLE REGRESSION MODEL PRE-PEAK PERIOD FOR OLEA

Extreme Values

			Case Number	Value
Mahalanobis Distance	Highest	1	21	26.80300
		2	9	22.80391
		3	23	21.76041
		4	48	21.20482
		5	2	19.15804
	Lowest	1	41	.48888
		2	36	.87589
		3	35	.93256
		4	31	1.02838
		5	4	1.33749

APPENDIX M4: MULTIPLE REGRESSION MODEL- POST- PEAK PERIOD FOR OLEA POLLEN

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.730[a]	.533	.523	2.69023

a. Predictors: (Constant), temperature maximum, four days running mean Olea pollen counts

b. Dependent Variable: normalised Olea pollen count in post-peak period

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	3.580	2.561		1.398	.165
	four days running mean Olea pollen counts	.060	.006	.713	9.664	.000
	temperature maximum	-.059	.092	-.047	-.643	.522

a. Dependent Variable: normalised Olea pollen count in post-peak period

APPENDIX M5: CORRELATION ANALYSIS BETWEEN NORMALISED OLEA POLLEN COUNTS AND METEREOLOGICAL VARIABLES DURING THE POST-PEAK PERIOD IN TIRANA

Correlations

		normalised Olea pollen count in post-peak period
temperature maximum	Pearson Correlation	-.281**
	Sig. (2-tailed)	.005
	N	99
temperature minimum	Pearson Correlation	-.125
	Sig. (2-tailed)	.216
	N	99
rainfall	Pearson Correlation	-.038
	Sig. (2-tailed)	.709
	N	99
five days running mean Olea pollen counts	Pearson Correlation	.723**
	Sig. (2-tailed)	.000
	N	99
four days running mean Olea pollen counts	Pearson Correlation	.729**
	Sig. (2-tailed)	.000
	N	99
three days running mean Olea pollen counts	Pearson Correlation	.719**
	Sig. (2-tailed)	.000
	N	99
two days running mean Olea pollen counts	Pearson Correlation	.722**
	Sig. (2-tailed)	.000
	N	99

**. Correlation is significant at the 0.01 level (2-tailed).

APPENDIX M6: MULTIPLE REGRESSION MODEL POST- PEAK PERIOD FOR OLEA

Extreme Values

			Case Number	Value
Mahalanobis Distance	Highest	1	5	10.32257
		2	91	8.72255
		3	6	8.41720
		4	90	8.07499
		5	7	8.02640
	Lowest	1	86	.01736
		2	14	.03601
		3	80	.05235
		4	71	.10173
		5	39	.12691

APPENDIX N : MODEL SUMMARY TABLES AND COEFFICIENTS TABLES PRODUCED BY SPSS FOLLOWING MULTIPLE REGRESSION ANALYSIS FOR OLEA ON NON-RAINY DAYS, TIRANA DATA

APPENDIX N1: MULTIPLE REGRESSION MODEL- PRE-PEAK PERIOD ON NON-RAINY DAYS

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.435[a]	.189	.151	4.21585

a. Predictors: (Constant), temperature minimum, five days running mean normalised Olea pollen count

b. Dependent Variable: normalised Olea on non -rainy days

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	-3.204	4.784		-.670	.507		
	five days running mean normalised Olea pollen count	.039	.022	.289	1.746	.088	.703	1.422
	temperature minimum	.426	.346	.204	1.231	.225	.703	1.422

a. Dependent Variable: normalised Olea on non -rainy days

APPENDIX N2: CORRELATION ANALYSIS BETWEEN NORMALISED OLEA POLLEN COUNTS AND METEREOLOGICAL VARIABLES DURING THE PRE-PEAK PERIOD IN TIRANA ON NON-RAINY DAYS

Correlations

		normalised Olea on non -rainy days
temperature maximum	Pearson Correlation	.205
	Sig. (2-tailed)	.176
	N	45
temperature minimum	Pearson Correlation	.361*
	Sig. (2-tailed)	.015
	N	45
five days running mean normalised Olea pollen count	Pearson Correlation	.400**
	Sig. (2-tailed)	.006
	N	45
four days running mean normalised Olea pollen count	Pearson Correlation	.218
	Sig. (2-tailed)	.151
	N	45
three days running mean normalised Olea pollen count	Pearson Correlation	.125
	Sig. (2-tailed)	.411
	N	45
two days running mean normalised Olea pollen count	Pearson Correlation	.153
	Sig. (2-tailed)	.314
	N	45

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

APPENDIX N3: MULTIPLE REGRESSION MODEL PRE-PEAK PERIOD FOR OLEA ON NON-RAINY DAYS

Extreme Values

			Case Number	Value
Mahalanobis Distance	Highest	1	70	7,06051
		2	71	6,49082
		3	46	5,74929
		4	44	5,55948
		5	47	5,15727
	Lowest	1	6	,03534
		2	55	,15542
		3	38	,16464
		4	13	,17014
		5	12	,21135

APPENDIX N4: MULTIPLE REGRESSION MODEL FOR OLEA IN THE POST-PEAK PERIOD ON NON-RAINY DAYS

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.614[a]	.376	.344	3.45264

a. Predictors: (Constant), two days running mean normalised Olea pollen couny, five days running mean normalised Olea pollen count

b. Dependent Variable: normalised Olea pollen count on non-rainy days

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	5.332	.709		7.525	.000		
	five days running mean normalised Olea pollen count	.021	.026	.230	.788	.436	.192	5.202
	two days running mean normalised Olea pollen couny	.038	.028	.398	1.364	.181	.192	5.202

a. Dependent Variable: normalised Olea pollen count on non-rainy days

APPENDIX N5: CORRELATION ANALYSIS BETWEEN NORMALISED OLEA POLLEN COUNTS AND METEREOLOGICAL VARIABLES DURING THE POST-PEAK PERIOD IN TIRANA ON NON-RAINY DAYS

Correlations

		normalised Olea pollen count on non-rainy days
temperature maximum	Pearson Correlation	-.186
	Sig. (2-tailed)	.245
	N	41
temperature minimum	Pearson Correlation	.169
	Sig. (2-tailed)	.291
	N	41
five days running mean normalised Olea pollen count	Pearson Correlation	.588**
	Sig. (2-tailed)	.000
	N	41
four days running mean normalised Olea pollen count	Pearson Correlation	.553**
	Sig. (2-tailed)	.000
	N	41
three days running mean normalised Olea pollen count	Pearson Correlation	.565**
	Sig. (2-tailed)	.000
	N	41
two days running mean normalised Olea pollen couny	Pearson Correlation	.605**
	Sig. (2-tailed)	.000
	N	41

**. Correlation is significant at the 0.01 level (2-tailed).

APPENDIX N6: MULTIPLE REGRESSION MODEL POST- PEAK PERIOD FOR OLEA POLLEN ON NON-RAINY DAYS

Extreme Values

			Case Number	Value
Mahalanobis Distance	Highest	1	1	20,05818
		2	4	9,80205
		3	3	7,41751
		4	2	7,07802
		5	30	6,55797
	Lowest	1	35	,00225
		2	34	,08093
		3	11	,10839
		4	12	,23199
		5	32	,23910

APPENDIX O: MODEL SUMMARY TABLE AND COEFFICIENTS TABLE PRODUCED BY SPSS FOLLOWING SIMPLE LINEAR REGRESSION ANALYSIS FOR TIRANA DATA FOR URTICACEAE

APPENDIX O1: SIMPLE LINEAR MODEL PREDICTING THE START OF POLLEN SEASON OF URTICACEAE

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.990[a]	.980	.971	.35355

a. Predictors: (Constant), temperature mean January(1-30)

b. Dependent Variable: Start date of Urticaceae pollen season

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	163.750	2.008		81.557	.000		
	temperature mean January(1-30)	-2.500	.250	-.990	-10.000	.010	1.000	1.000

a. Dependent Variable: Start date of Urticaceae pollen season

APPENDIX O2: SIMPLE LINEAR MODEL PREDICTING THE END OF THE URTICACEAE POLLEN SEASON

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.999[a]	.998	.997	.81685

a. Predictors: (Constant), rainfall total in march

b. Dependent Variable: End date of Urticaceae pollen season

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	305.828	.737		414.704	.000		
	rainfall total in march	-.144	.004	-.999	-32.699	.001	1.000	1.000

a. Dependent Variable: End date of Urticaceae pollen season

APPENDIX O3: SIMPLE LINEAR MODEL PREDICTING THE SEVERITY OF URTICACEAE POLLEN SEASON

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.987[a]	.974	.962	99.16735

a. Predictors: (Constant), tmax 91-110

b. Dependent Variable: Severity of Urticaceae pollen season

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	8116.483	793.408		10.230	.009
	tmax 91-110	-365.933	41.953	-.987	-8.723	.013

a. Dependent Variable: Severity of Urticaceae pollen season

APPENDIX O4: SIMPLE LINEAR MODEL PREDICTING THE LENGTH OF URTICACEAE POLLEN SEASON

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.989[a]	.977	.966	2.89652

a. Predictors: (Constant), rainfall total in march

b. Dependent Variable: Length of the Urticaceae pollen season with 5%method

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	162.132	2.615		62.000	.000		
	rainfall total in march	-.144	.016	-.989	-9.246	.011	1.000	1.000

a. Dependent Variable: Length of the Urticaceae pollen season with 5%method

APPENDIX O5: SIMPLE LINEAR MODEL PREDICTING THE START OF THE PEAK PERIOD FOR URTICACEAE POLLEN SEASON

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.952[a]	.907	.860	2.04970

a. Predictors: (Constant), rain days 11-20

b. Dependent Variable: Start of peak period for Urticaceae

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	156.840	1.502		104.412	.000		
	rain days 11-20	-.997	.226	-.952	-4.407	.048	1.000	1.000

a. Dependent Variable: Start of peak period for Urticaceae

APPENDIX O6: SIMPLE LINEAR MODEL PREDICTING THE END DATE OF THE PEAK PERIOD FOR URTICACEAE POLLEN SEASON

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.995[a]	.990	.985	1.74181

a. Predictors: (Constant), rain 61-80

b. Dependent Variable: End of peak period for Urticaceae

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	270.583	1.610		168.106	.000		
	rain 61-80	-3.855	.273	-.995	-14.097	.005	1.000	1.000

a. Dependent Variable: End of peak period for Urticaceae

APPENDIX P: MODEL SUMMARY TABLES AND COEFFICIENTS TABLES PRODUCED BY SPSS FOLLOWING MULTIPLE REGRESSION ANALYSIS FOR URTICACEAE, TIRANA DATA

APPENDIX P1: MULTIPLE REGRESSION MODEL- PRE-PEAK PERIOD

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.668[a]	.446	.438	1.32686

a. Predictors: (Constant), Temperature maximum, three days running mean

b. Dependent Variable: normalised Urticaceae pollen

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	.303	.652		.464	.643		
	three days running mean	.115	.013	.598	8.750	.000	.854	1.171
	Temperature maximum	.056	.026	.148	2.164	.032	.854	1.171

a. Dependent Variable: normalised Urticaceae pollen

APPENDIX P2: CORRELATION ANALYSIS BETWEEN NORMALISED URTICACEAE POLLEN COUNTS AND METEREOLOGICAL VARIABLES DURING THE PRE-PEAK PERIOD IN TIRANA

Correlations

		normalised Urticaceae pollen
five days running mean	Pearson Correlation	.629**
	Sig. (2-tailed)	.000
	N	142
four days running mean	Pearson Correlation	.650**
	Sig. (2-tailed)	.000
	N	142
three days running mean	Pearson Correlation	.654**
	Sig. (2-tailed)	.000
	N	142
two days running mean	Pearson Correlation	.646**
	Sig. (2-tailed)	.000
	N	142
Temperature maximum	Pearson Correlation	.376**
	Sig. (2-tailed)	.000
	N	142
Temperature minimum	Pearson Correlation	.188*
	Sig. (2-tailed)	.025
	N	142
Rainfall	Pearson Correlation	-.177*
	Sig. (2-tailed)	.035
	N	142

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

APPENDIX P3: MULTIPLE REGRESSION MODEL PRE-PEAK PERIOD FOR URTICACEAE

Extreme Values

			Case Number	Value
Mahalanobis Distance	Highest	1	56	29,11082
		2	86	12,27281
		3	85	11,98781
		4	84	8,76329
		5	87	8,55770
	Lowest	1	34	,01045
		2	123	,03062
		3	25	,03062
		4	81	,04649
		5	24	,06812

APPENDIX P4: MULTIPLE REGRESSION MODEL FOR URTICACEAE IN THE PEAK PERIOD

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.678[a]	.459	.456	1.26343

a. Predictors: (Constant), Temperature minimum, two days running mean

b. Dependent Variable: normalised Urticaceae pollen

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	2.965	.471		6.293	.000		
	two days running mean	.126	.008	.623	15.065	.000	.969	1.032
	Temperature minimum	-.105	.024	-.178	-4.292	.000	.969	1.032

a. Dependent Variable: normalised Urticaceae pollen

APPENDIX P5: CORRELATION ANALYSIS BETWEEN NORMALISED URTICACEAE POLLEN COUNTS AND METEREOLOGICAL VARIABLES DURING THE PEAK PERIOD IN TIRANA

Correlations

		normalised Urticaceae pollen
five days running mean	Pearson Correlation	.625**
	Sig. (2-tailed)	.000
	N	329
four days running mean	Pearson Correlation	.642**
	Sig. (2-tailed)	.000
	N	329
three days running mean	Pearson Correlation	.648**
	Sig. (2-tailed)	.000
	N	329
two days running mean	Pearson Correlation	.655**
	Sig. (2-tailed)	.000
	N	329
Temparature maximum	Pearson Correlation	-.219**
	Sig. (2-tailed)	.000
	N	329
Temperature minimum	Pearson Correlation	-.288**
	Sig. (2-tailed)	.000
	N	329
Rainfall	Pearson Correlation	-.098
	Sig. (2-tailed)	.094
	N	295

**. Correlation is significant at the 0.01 level (2-tailed).

APPENDIX P6: MULTIPLE REGRESSION MODEL PEAK PERIOD FOR URTICACEAE POLLEN

Extreme Values

			Case Number	Value
Mahalanobis Distance	Highest	1	36	20.65359
		2	2	15.20184
		3	3	14.33953
		4	35	13.71303
		5	1	12.22938
	Lowest	1	151	.00957
		2	133	.02094
		3	327	.02334
		4	132	.02334
		5	305	.03713

APPENDIX P7: MULTIPLE REGRESSION MODEL- POST- PEAK PERIOD FOR URTICACEAE POLLEN

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.572[a]	.328	.320	1.12147

a. Predictors: (Constant), Temperature minimum, three days running mean

b. Dependent Variable: normalised Urticaceae

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	.407	.377		1.078	.282		
	three days running mean	.117	.015	.515	7.814	.000	.901	1.110
	Temperature minimum	.058	.028	.136	2.061	.041	.901	1.110

a. Dependent Variable: normalised Urticaceae

APPENDIX P8: CORRELATION ANALYSIS BETWEEN NORMALISED URTICACEAE POLLEN COUNTS AND METEREOLOGICAL VARIABLES DURING THE POST-PEAK PERIOD IN TIRANA

Correlations

		normalised Urticaceae
five days running mean	Pearson Correlation	.501**
	Sig. (2-tailed)	.000
	N	175
four days running mean	Pearson Correlation	.524**
	Sig. (2-tailed)	.000
	N	175
three days running mean	Pearson Correlation	.558**
	Sig. (2-tailed)	.000
	N	175
two days running mean	Pearson Correlation	.544**
	Sig. (2-tailed)	.000
	N	175
Temparature maximum	Pearson Correlation	.282**
	Sig. (2-tailed)	.000
	N	175
Temperature minimum	Pearson Correlation	.298**
	Sig. (2-tailed)	.000
	N	175
Rainfall	Pearson Correlation	.153*
	Sig. (2-tailed)	.044
	N	175

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

APPENDIX P9: MULTIPLE REGRESSION MODEL POST- PEAK PERIOD FOR URTICACEAE POLLEN

Extreme Values

			Case Number	Value
Mahalanobis Distance	Highest	1	61	13.27871
		2	1	13.01838
		3	60	12.86626
		4	2	10.43683
		5	4	10.13800
	Lowest	1	124	.00042
		2	92	.04478
		3	110	.04596
		4	104	.08341
		5	166	.12369

APPENDIX Q: MODEL SUMMARY TABLES AND COEFFICIENTS TABLES PRODUCED BY SPSS FOLLOWING MULTIPLE REGRESSION ANALYSIS FOR URTICACEAE ON NON-RAINY DAYS, TIRANA DATA

APPENDIX Q1: MULTIPLE REGRESSION MODEL- PRE-PEAK PERIOD ON NON-RAINY DAYS

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	,578[a]	,334	,321	1,39934

a. Predictors: (Constant), three days running mean, four days running mean

b. Dependent Variable: normalised Urticaceae pre-peak non-rainy-days

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	2,012	,233		8,642	,000		
	four days running mean	,050	,066	,259	,757	,451	,058	17,196
	three days running mean	,061	,064	,324	,947	,346	,058	17,196

a. Dependent Variable: normalised Urticaceae pre-peak non-rainy-days

APPENDIX Q2: CORRELATION ANALYSIS BETWEEN NORMALISED URTICACEAE POLLEN COUNTS AND METEREOLOGICAL VARIABLES DURING THE PRE-PEAK PERIOD IN TIRANA ON NON-RAINY DAYS

Correlations

		normalised Urticaceae pre-peak non-rainy-days
five days running mean	Pearson Correlation	,541**
	Sig. (2-tailed)	,000
	N	101
four days running mean	Pearson Correlation	,573**
	Sig. (2-tailed)	,000
	N	101
three days running mean	Pearson Correlation	,575**
	Sig. (2-tailed)	,000
	N	101
two days running mean	Pearson Correlation	,562**
	Sig. (2-tailed)	,000
	N	101
temparature maximum	Pearson Correlation	,122
	Sig. (2-tailed)	,224
	N	101
temperature minimum	Pearson Correlation	-,086
	Sig. (2-tailed)	,394
	N	101

**. Correlation is significant at the 0.01 level (2-tailed).

APPENDIX Q3: MULTIPLE REGRESSION MODEL PRE-PEAK PERIOD FOR URTICACEAE ON NON-RAINY DAYS

Extreme Values

			Case Number	Value
Mahalanobis Distance	Highest	1	67	18,04140
		2	65	16,09158
		3	66	10,66536
		4	68	9,25324
		5	64	9,18023
	Lowest	1	48	,00910
		2	9	,09425
		3	91	,15694
		4	33	,16255
		5	40	,17624[a]

a. Only a partial list of cases with the value ,17624 are shown in the table of lower extremes.

APPENDIX Q4: MULTIPLE REGRESSION MODEL FOR URTICACEAE IN THE PEAK PERIOD ON NON-RAINY DAYS

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	,689[a]	,475	,471	1,20345

a. Predictors: (Constant), two days running mean, temperature minimum

b. Dependent Variable: normalised Urticaceae peak non-rainy-days

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	3,377	,502		6,729	,000		
	temperature minimum	-,127	,026	-,228	-4,888	,000	,964	1,037
	two days running mean	,127	,010	,609	13,089	,000	,964	1,037

a. Dependent Variable: normalised Urticaceae peak non-rainy-days

APPENDIX Q5: CORRELATION ANALYSIS BETWEEN NORMALISED URTICACEAE POLLEN COUNTS AND METEREOLOGICAL VARIABLES DURING THE PEAK PERIOD IN TIRANA ON NON-RAINY DAYS

Correlations

		normalised Urticaceae peak non-rainy-days
five days running mean	Pearson Correlation	,629**
	Sig. (2-tailed)	,000
	N	254
four days running mean	Pearson Correlation	,639**
	Sig. (2-tailed)	,000
	N	254
three days running mean	Pearson Correlation	,643**
	Sig. (2-tailed)	,000
	N	254
two days running mean	Pearson Correlation	,652**
	Sig. (2-tailed)	,000
	N	254
temperature maximum	Pearson Correlation	-,317**
	Sig. (2-tailed)	,000
	N	254
temperature minimum	Pearson Correlation	-,342**
	Sig. (2-tailed)	,000
	N	254

**. Correlation is significant at the 0.01 level (2-tailed).

APPENDIX Q6: MULTIPLE REGRESSION MODEL PEAK PERIOD FOR URTICACEAE POLLEN ON NON-RAINY DAYS

Extreme Values

			Case Number	Value
Mahalanobis Distance	Highest	1	24	23,84102
		2	1	17,57628
		3	195	12,02812
		4	10	9,77243
		5	194	9,20591
	Lowest	1	114	,01298
		2	113	,01979
		3	129	,02028
		4	140	,02751
		5	145	,04855

APPENDIX: X

Appendix X1: Results of ANOVA (SPSS output) of normalized pollen data and wind directions for grass

Descriptives

normalised Grass

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
1,00	56	3,8750	2,35150	,31423	3,2453	4,5047	1,00	11,00
2,00	18	3,1111	1,45072	,34194	2,3897	3,8325	1,00	6,00
3,00	66	3,7727	2,76125	,33989	3,0939	4,4515	,00	14,00
4,00	168	3,8155	2,48743	,19191	3,4366	4,1944	,00	10,00
Total	308	3,7760	2,47301	,14091	3,4987	4,0533	,00	14,00

Test of Homogeneity of Variances

normalised Grass

Levene Statistic	df1	df2	Sig.
2,098	3	304	,100

ANOVA

normalised Grass

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	8,769	3	2,923	,475	,700
Within Groups	1868,773	304	6,147		
Total	1877,542	307			

Appendix X2: Results of ANOVA (SPSS output) of normalized pollen data and wind speed for grass

Descriptives

normalised Grass

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1,00	80	3,5125	2,21613	,24777	3,0193	4,0057	,00	11,00
2,00	82	3,9024	2,58490	,28545	3,3345	4,4704	,00	14,00
3,00	105	4,1905	2,73192	,26661	3,6618	4,7192	,00	10,00
4,00	41	2,9756	1,73908	,27160	2,4267	3,5245	,00	8,00
Total	308	3,7760	2,47301	,14091	3,4987	4,0533	,00	14,00

Test of Homogeneity of Variances

normalised Grass

Levene Statistic	df1	df2	Sig.
3,965	3	304	,009

ANOVA

normalised Grass

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	51,169	3	17,056	2,839	,038
Within Groups	1826,373	304	6,008		
Total	1877,542	307			

Appendix X3: Results of Kruskal Wallace test (SPSS output) of normalized pollen data and wind speed for grass

Ranks

	wind speed for four	N	Mean Rank
normalised Grass	1,00	138	146,23
	2,00	65	149,67
	3,00	45	146,39
	4,00	60	184,83
	Total	308	

Test Statistics[a,b]

	normalised Grass
Chi-Square	8,949
df	3
Asymp. Sig.	,030

a. Kruskal Wallis Test

b. Grouping Variable: wind speed for four groups for grass

Appendix X4: Results of Kruskal Wallace test (SPSS output) of normalized pollen data and wind directions for grass

Ranks

	wind dir grass	N	Mean Rank
normalised Grass	0-210	80	146,09
	211-300	82	159,60
	301-340	105	166,83
	341+	41	129,13
	Total	308	

Test Statistics[a,b]

	normalised Grass
Chi-Square	6,492
df	3
Asymp. Sig.	,090

a. Kruskal Wallis Test

b. Grouping Variable: wind dir grass percentilesgr2

Appendix X5: Results of ANOVA (SPSS output) of normalized pollen data and wind speed for Olea

Descriptives

normalised Grass

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
1,00	33	3,6667	2,65361	,46193	2,7257	4,6076	1,00	11,00
2,00	45	4,6889	4,08335	,60871	3,4621	5,9157	,00	16,00
3,00	47	4,5532	3,65233	,53275	3,4808	5,6256	,00	17,00
4,00	9	5,8889	5,23078	1,74359	1,8682	9,9096	1,00	13,00
Total	134	4,4701	3,71279	,32074	3,8357	5,1046	,00	17,00

Test of Homogeneity of Variances

normalised Grass

Levene Statistic	df1	df2	Sig.
4,649	3	130	,004

ANOVA

normalised Grass

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	41,897	3	13,966	1,013	,389
Within Groups	1791,484	130	13,781		
Total	1833,381	133			

Appendix X6: Results of Kruskal Wallace test (SPSS output) of normalized pollen data and wind directions for Olea

Ranks

	wind direction for olea gr1	N	Mean Rank
normalised Olea polen	0-90	20	64,20
	91-180	11	60,27
	181-270	37	71,70
	271+	66	67,35
	Total	134	

Test Statistics[a,b]

	normalised Olea polen
Chi-Square	,977
df	3
Asymp. Sig.	,807

a. Kruskal Wallis Test

b. Grouping Variable: wind direction for olea gr1

Appendix X7: Results of Kruskal Wallace test (SPSS output) of normalized pollen data and wind speed for Olea

Ranks

	wind dir in 4 groups	N	Mean Rank
normalised Grass	1,00	33	62,14
	2,00	45	67,89
	3,00	47	69,97
	4,00	9	72,33
	Total	134	

Test Statistics[a,b]

	normalised Grass
Chi-Square	,980
df	3
Asymp. Sig.	,806

a. Kruskal Wallis Test

b. Grouping Variable: wind dir in 4 groups

Appendix X8: Results of ANOVA (SPSS output) of normalized pollen data and wind directions for Olea

Descriptives

normalised Olea polen

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
0-217	33	3,6667	2,65361	,46193	2,7257	4,6076	1,00	11,00
218-270	35	5,2286	4,34596	,73460	3,7357	6,7215	,00	16,00
271-320	34	5,0588	4,01468	,68851	3,6580	6,4596	,00	17,00
321+	32	3,8438	3,44645	,60925	2,6012	5,0863	,00	13,00
Total	134	4,4701	3,71279	,32074	3,8357	5,1046	,00	17,00

Test of Homogeneity of Variances

normalised Olea polen

Levene Statistic	df1	df2	Sig.
3,210	3	130	,025

ANOVA

normalised Olea polen

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	65,775	3	21,925	1,612	,190
Within Groups	1767,606	130	13,597		
Total	1833,381	133			

Appendix X9: Results of ANOVA (SPSS output) of normalized pollen data and wind directions for Urticaceae

Descriptives

normalised Urticaceae

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
0-220	159	2,4088	1,77255	,14057	2,1312	2,6864	,00	8,00
221-320	203	2,1872	1,69870	,11923	1,9521	2,4223	,00	6,00
321-340	99	1,6869	1,55607	,15639	1,3765	1,9972	,00	7,00
340+	101	2,4653	1,72374	,17152	2,1251	2,8056	,00	6,00
Total	562	2,2117	1,71696	,07243	2,0695	2,3540	,00	8,00

Test of Homogeneity of Variances

normalised Urticaceae

Levene Statistic	df1	df2	Sig.
,749	3	558	,523

ANOVA

normalised Urticaceae

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	40,066	3	13,355	4,618	,003
Within Groups	1613,736	558	2,892		
Total	1653,802	561			

Appendix X10: Results of ANOVA (SPSS output) of normalized pollen data and wind directions for Urticaceae

Descriptives

normalised Urticaceae

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
0-4	195	2,7846	1,61653	,11576	2,5563	3,0129	,00	7,00
5-6	105	1,8000	1,55909	,15215	1,4983	2,1017	,00	6,00
7-10	251	1,9602	1,75682	,11089	1,7418	2,1786	,00	8,00
10+	11	1,7273	1,48936	,44906	,7267	2,7278	,00	4,00
Total	562	2,2117	1,71696	,07243	2,0695	2,3540	,00	8,00

Test of Homogeneity of Variances

normalised Urticaceae

Levene Statistic	df1	df2	Sig.
,140	3	558	,936

ANOVA

normalised Urticaceae

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	100,265	3	33,422	12,004	,000
Within Groups	1553,537	558	2,784		
Total	1653,802	561			

Appendix X11: Results of Kruskal Wallace test (SPSS output) of normalized pollen data and wind speed for Urticaceae

Ranks

	wind speed in	N	Mean Rank
normalised Urticaceae	0-4	195	339,27
	5-6	105	244,24
	7-10	251	254,04
	10+	11	239,68
	Total	562	

Test Statistics[a,b]

	normalised Urticaceae
Chi-Square	39,657
df	3
Asymp. Sig.	,000

a. Kruskal Wallis Test

b. Grouping Variable: wind speed in foor groups

Appendix X12: Results of Kruskal Wallace test (SPSS output) of normalized pollen data and wind speed for Urticaceae

Ranks

	wind dirce	N	Mean Rank
normalised Urticaceae	0-220	159	298,05
	221-320	203	279,90
	321-340	99	233,47
	340+	101	305,75
	Total	562	

Test Statistics[a,b]

	normalised Urticaceae
Chi-Square	13,093
df	3
Asymp. Sig.	,004

a. Kruskal Wallis Test

b. Grouping Variable: wind dirce according 4 groups

APENDIX XH

THE METEREOLOGICAL FEATURES FOR THE YEAR 2003

The whole of Europe faced an unexpected heat wave especially during the months of June, July and August. The results from the global temperature register show that the year 2003 was the hottest year since year 1861 which is the first year when the regular meteorological parameters have been recorded.

In Albania the increase of temperatures has been recorded during the months of May, June, July and August. This is very evident in the increase of maximum and minimum temperatures. A decrease of total rainfall amount has been observed in 2003.

SOME CONCLUSIONS IN RELATION TO THE MAXIMUM AND MINIMUM TEMPERATURES

- The annual average maximum temperature recorded in 2003 were up to 2.5^{o}C above the maximum multi annual value for the period 1961-1990 (Fig.52)
- The maximal deviance of 7^{o}C in relation to the multi annual mean was recorded in May for the rural area and June for the lowland areas. The values of recorded temperatures in 2003 are the highest recorded compared with the period 1961-1990 specially for the months of May and June
- However, the absolute maximum temperatures recorded in 2003 generally have not reached the absolute maximum recorded during the period between 1961-1990. These values were 2 to7^{o}C below the normal values.

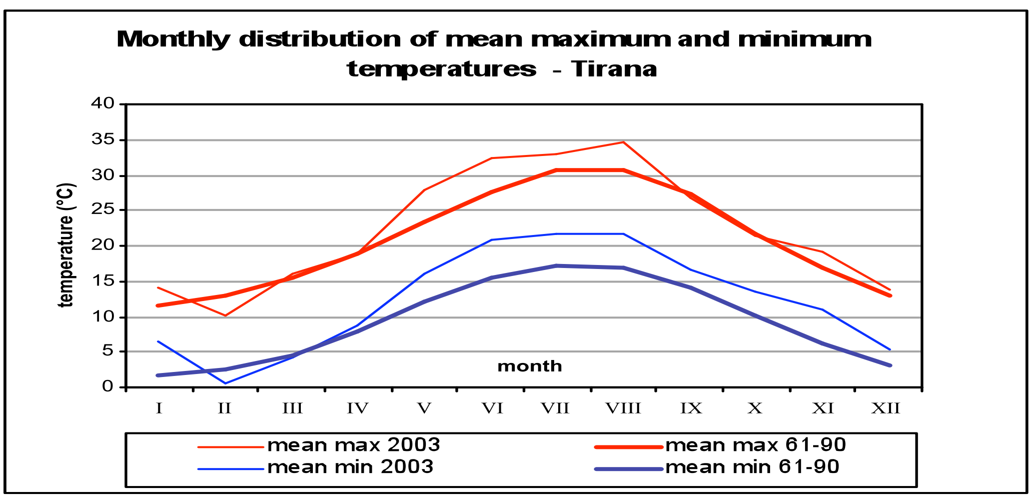


Fig.52

The minimum temperatures had the following listed features:

- The annual mean minimum temperatures recorded in 2003 have been 3°C above the mean multi annual value (the period 1961-1990). This has been shown in figure 53.
- The mean minimum temperatures have been higher than the multi annual from May till August. They reach the highest at 5°C above the mean value in June
- In general, January is the coldest month of the year in Albania, however in 2003 the recorded coldest month was February.
- The mean minimum temperature in February in 2003 was 5.5°C below the mean value multi annual (for the period 1961-1990)
- The absolute minimum temperatures in general have been 10°C above absolute minimum temperatures registered during the year 1960-1990
- The figure below shows the dynamic of the air mean temperature anomaly:

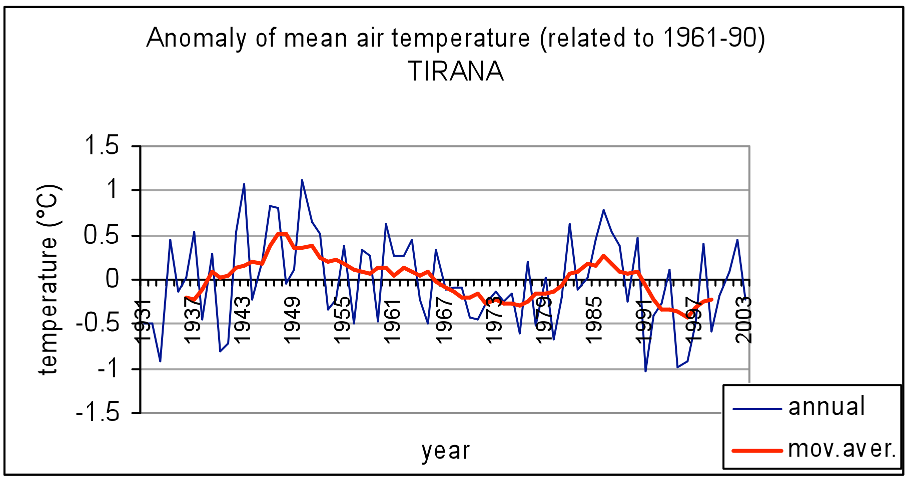


Fig.53

SOME CONCLUSIONS IN RELATION TO RAINFALL

- The quantity of rainfall in 2003 in Albania has been below the normal values (approximately 60% of annual mean). This is shown in figure 54.
- November has been the wettest month of the year for the period between1961-1990. October 2003 has been the wettest month for all Albania. The recorded values have been 150% to 300% above the norm for some mountainous areas in northeast and northwest of Albania.
- The month of March is the driest month in 2003 but also the driest of the all years observed (Figure 55).

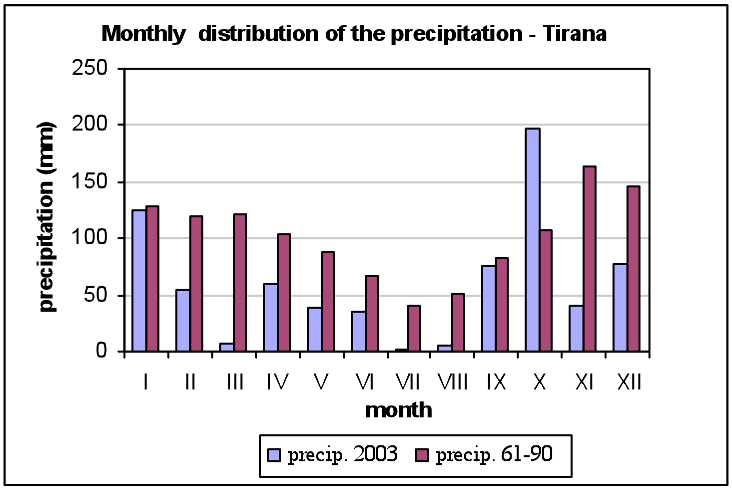

Monthly distribution of the precipitation - Tirana
precipitation (mm)
250
200
150
100
50
0
I
II
III
IV
V
VI
VII
VIII
IX
X
XI
XII
month
precip. 2003
precip. 61-90

Fig.54

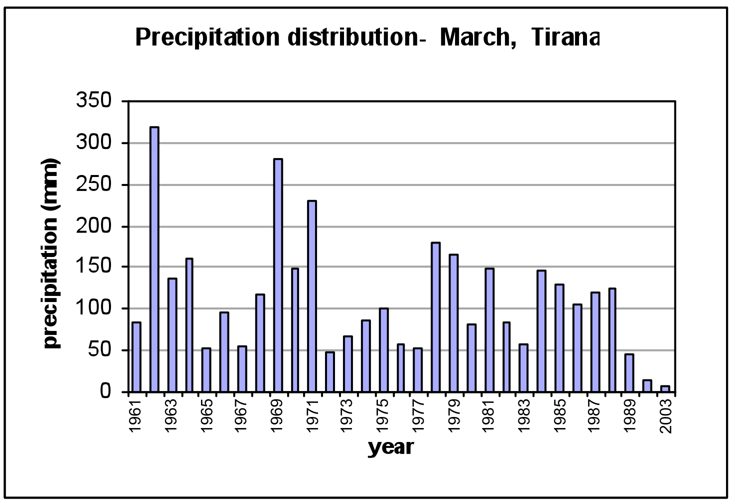

Precipitation distribution- March, Tirana
precipitation (mm)
350
300
250
200
150
100
50
0
1961
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
2003
year

Fig.55

THE METEREOLOGICAL FEATURES FOR THE YEAR 2004

SOME CONCLUSIONS IN RELATION TO THE MAXIMUM AND MINIMUM TEMPERATURES

- In general the mean maximum temperatures for the 2004 were higher than the mean maximum temperatures for the multi annual values. It should be noted that the month of October is characterized by very high values when compared with the norm. In some cities like Kukes, Puke, Elbasan and Cerrik the values for the maximum temperature have been higher in all the series of recorded values. The month of May has been characterized throughout Albania by lower values than the norm (by approximately 2.5^{o}C).
- In Tirana the values of mean maximum temperature have a negative deviance of -1.4^{o}C in May and positive deviance of 1.7^{o}C in December when compared with the multi annual values (Fig.56).
- The mean minimum temperatures have an negative deviance of -2.3^{o}C in May when compared with the multi annual values and a positive deviance of 3^{o}C in December. There were some values which are above the multi annual values which have been registered in Tirana with values of 4.7^{o}C in October and 0.5^{o}C in May. In areas like Pogradec, Korca and Kukes a reverse phenomenon has occurred where the mean temperature values were lower than the multi annual values with an deviance of -5.1^{o}C in May and -2.9^{o}C in October.
- The mean minimum temperature for Tirana in 2004 are above the multi annual values with a maximum of 2.1^{o}C on October and an negative deviance of -1.6^{o}C in January.
- In Tirana in 2004 the mean minimum temperatures values are above the multi annual values with values of -4.7^{o}C in October and 0.5^{o}C in May (Fig.57).

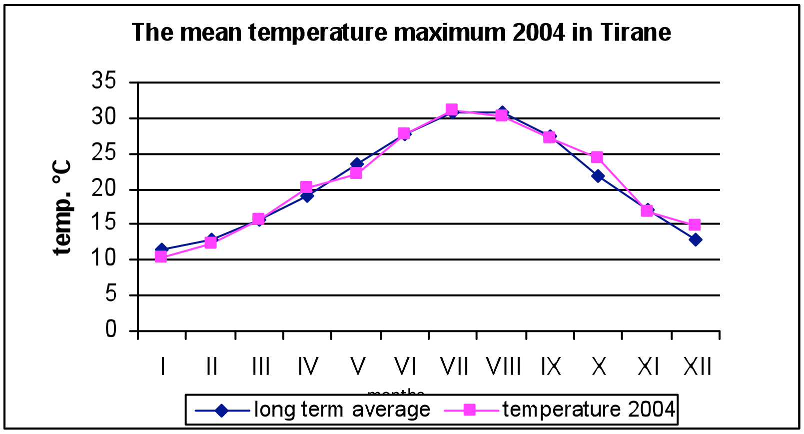


Fig.56

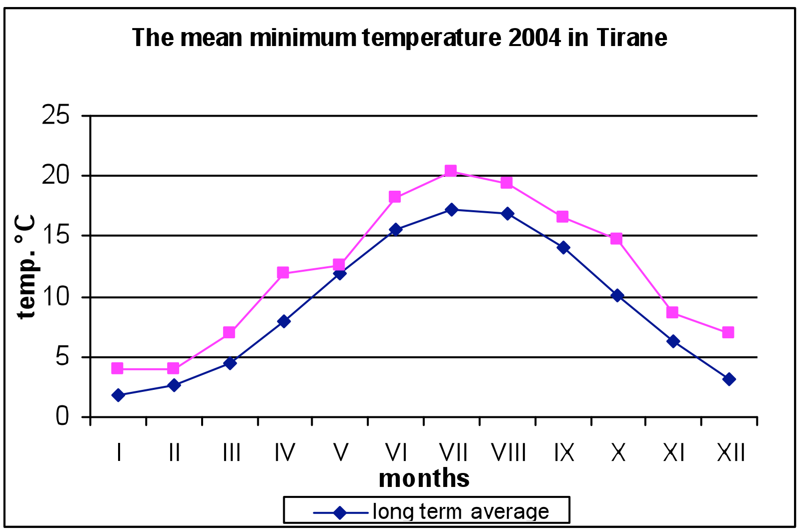


Fig.57

SOME CONCLUSIONS IN RELATION TO THE RAINFALL

In general 2004 was characterized by abundant rainfall amounts which surpassed the multi annual mean not only during the winter months but also during the summer with the exception of August. In 2004 August was the driest month of the year with the amount of rainfall being 0.2 times lower then the multi annual rainfall amount.

In the north and midland areas the total rainfall amount was registered during the winter with a maximum amount in January and November. The maximum amount of rainfall in

Tirana is registered in January with a total of 200mm and in November with a total of rainfall of 129.4 mm (Fig.58).

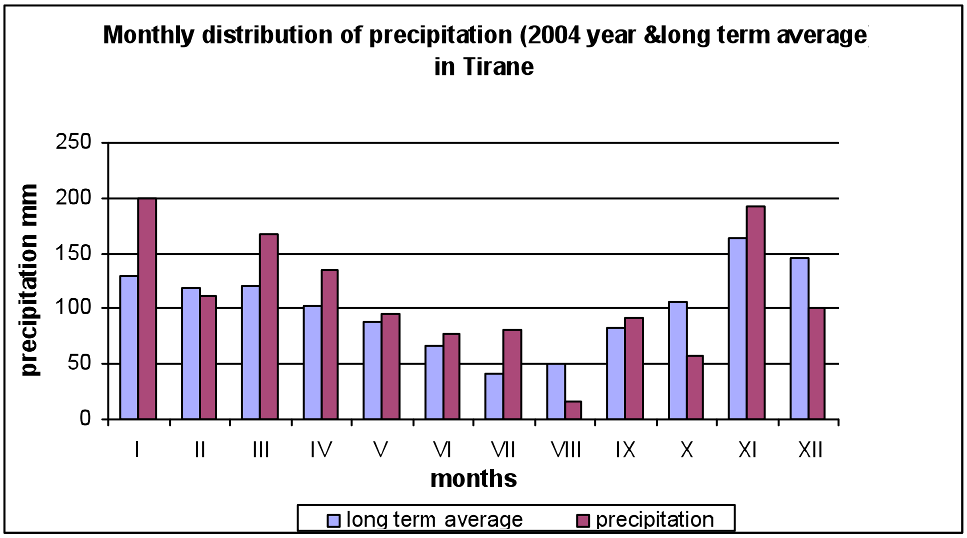


Fig.58